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From N. H. Darton,
U. S. Geological Survey,
Washington, D. C.

59TH CONGRESS, 1st Session. | SENATE. | DOCUMENT No. 219.

GEOLOGY

OF THE

OWL CREEK MOUNTAINS,

WITH

NOTES ON RESOURCES OF ADJOINING REGIONS IN THE CEDED PORTION OF THE SHOSHONE INDIAN RESERVATION, WYOMING.

By N. H. DARTON,
United States Geological Survey.

FEBRUARY 15, 1906.—Ordered to be printed, with illustrations.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1906.

LETTERS OF TRANSMITTAL.

Department of the Interior,
Washington, February 12, 1906.

Sir: I am in receipt of Senate resolution of the 5th instant: "That the Secretary of the Interior be directed to furnish to the Senate such information relating to the geology and the natural resources of that portion of the Shoshone Reservation which is to be opened for settlement in July, 1906, as may be in the possession of the Geological Survey."

In response thereto I have the honor to transmit herewith copy of a letter from the Director of the Geological Survey transmitting a report on the geology of the Owl Creek Mountains, with notes on resources of adjoining regions in the ceded portion of the Shoshone Indian Reservation, Wyo.

Very respectfully,

E. A. Hitchcock,
Secretary.

The President of the Senate.

February 12, 1906.

Sir: In accordance with Senate resolution No. 74, I forward herewith a report on the geology of the Owl Creek Mountains, with notes on resources of adjoining regions in the ceded portions of the Shoshone Indian Reservation, Wyo., by N. H. Darton. This embodies all the information that we have relating to the reservation.

Very respectfully,

Chas. D. Walcott, *Director.*

The Secretary of the Interior.

Mus. Lab. bookplate

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GEOLOGY OF THE OWL CREEK MOUNTAINS,

WITH NOTES ON RESOURCES OF ADJOINING REGIONS IN THE CEDED PORTION OF THE SHOSHONE INDIAN RESERVATION, WYO.

By N. H. Darton,
United States Geological Survey.

INTRODUCTION.

During the summer of 1905 a reconnaissance was made of the greater portion of the Shoshone or Wind River Indian Reservation north of Wind River, in central Wyoming, the results of which are stated in the following pages. The area examined is shown on Pls. II and XVII. It lies mainly in the portion of the reservation which is to be opened to settlement in 1906, but on the north it extends across the southern margin of Bighorn County. Much more attention was given to the Owl Creek Mountains, with their diversified and interesting geology, than to the plains and bad lands of the Wind River basin.

The writer was assisted in the work by Mr. C. A. Fisher, who mapped a considerable part of the area, and by Mr. E. G. Woodruff, who served as geologic aid. A reconnaissance topographic survey was made, based on level lines of the United States Geological Survey, which cross the mountains on the Lander road south of Thermopolis and from Anchor to Hollands and extend along Owl Creek. The area west of longitude 109° is covered by the Kirwin topographic sheet of the United States Geological Survey. The course of Bighorn Canyon was platted from a detailed survey made by the Chicago, Burlington and Quincy Railway Company, kindly furnished by Mr. T. E. Calvert, chief engineer. Many of the elevations were determined by an aneroid barometer.

The geology of the region has never before been described, except by Mr. G. E. Eldridge, who crossed it along two lines of travel during the summer of 1893, and ascertained some of the salient features.[a] Mr. T. B. Comstock crossed the mountains near Anchor in 1873, and briefly described the general structure along his route.

The ceded portion of the Shoshone Indian Reservation is the area lying north of Wind River and east of Popo Agie and Bighorn rivers. It lies in the northern central portion of Fremont County, Wyo., and includes also a small corner of Bighorn County adjoining Bighorn Canyon south of Thermopolis. The total area is about 2,000 square miles. The northern third of this area lies in the Owl Creek and Shoshone mountains and the southern portion comprises a wide region of rolling plains in the Wind River basin. The area is bordered on the south by Wind River and its eastern margin is crossed by Bighorn River. These streams carry a large volume of water and flow in flat-bottomed valleys, along which there is a moderate acreage of land which is immediately valuable for agriculture.

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[a] Geological reconnaissance in northwest Wyoming: Bull. U. S. Geol. Survey No. 119, 1894.

With a mean average rainfall of about 13 inches a year, the climate is too arid for the raising of crops without irrigation, but a large amount of water in the two principal rivers is available for this use. Along the bottom lands bordering the rivers the water can be taken out in small ditches, though, owing to the spring floods, there will be difficulty in maintaining these ditches and especially their head gates, and the amount of land that can be irrigated by this means is small. By the construction of irrigation canals, however, wide areas of the basin lands could be brought under cultivation, especially if the flood waters of the mountain slopes were stored for use during the dry season. The greater part of the region is well adapted for grazing and this undoubtedly will be its principal use. Fully two-thirds of the land bears a fair growth of nutritious grasses, and water for stock is within reach, excepting in a few districts.

In portions of the Owl Creek Mountains are exposed granites and associated schists which contain gold and other ores, possibly in sufficient amount to be of economic importance. In the south end of Shoshone Mountains, which constitute the northwest corner of the ceded area, there may possibly be found a southern extension of the mineral veins of the Kirwin region. Coal deposits occur in the center of the area, and though they may not merit extensive working they will afford a useful local supply.

The only settlers now in the ceded area are a few Indians and white men who have married squaws, and the ranches of these persons are widely scattered along the rivers and on the creeks near the foot of the mountains.

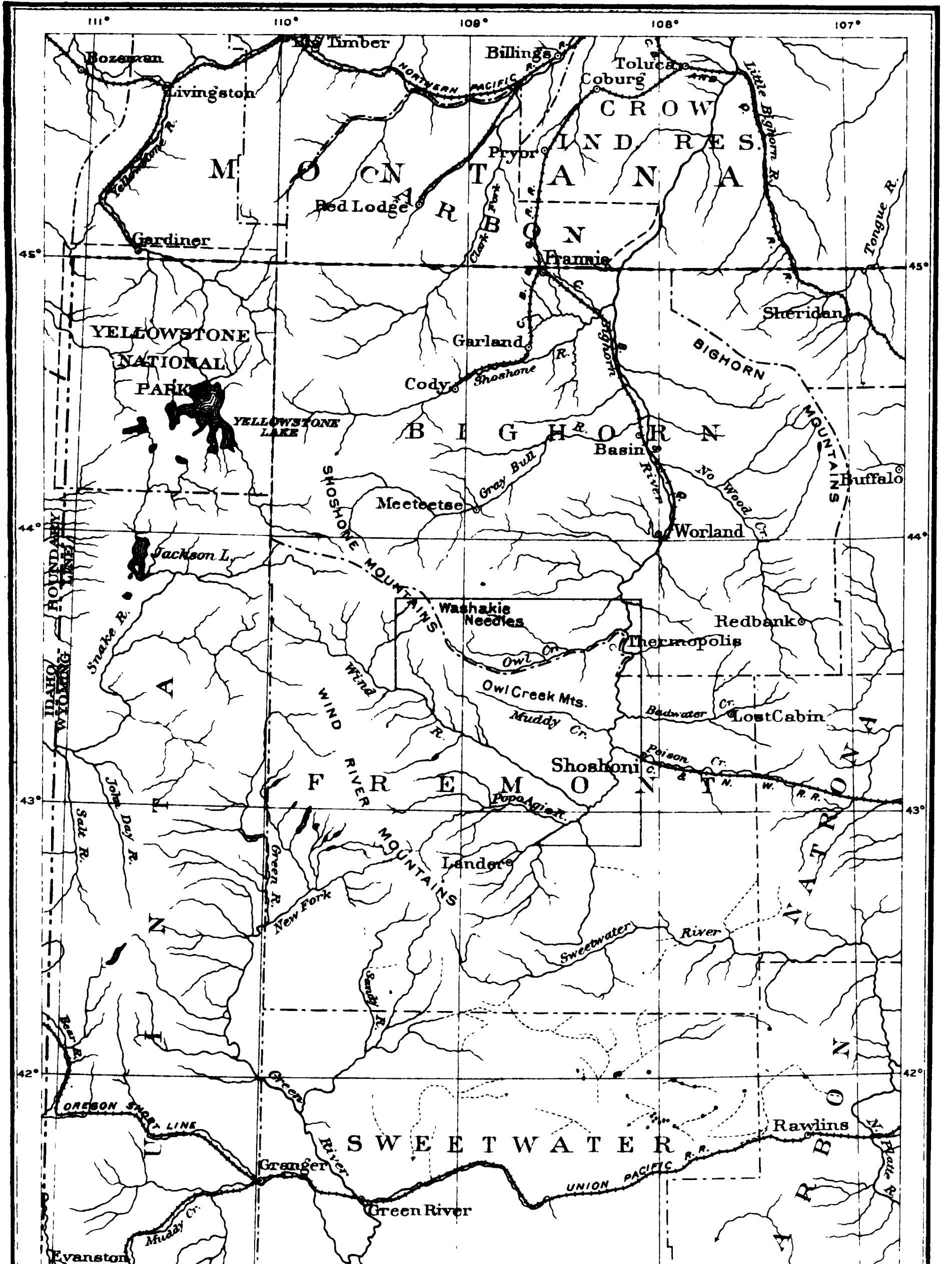
GEOGRAPHY.

TOPOGRAPHIC FEATURES.

The portion of the Shoshone Reservation which is to be opened to settlement in 1906 consists mainly of the northern part of the Wind River basin, the Owl Creek Mountains, and the southern termination of the Shoshone Mountains. Some of the features are shown in Pls. II and XVII. The Wind River basin is a wide area of rolling plains extending northward from the foot of the Wind River Mountains to the foot of the Owl Creek and Shoshone mountains. On its east side, where Wind River and Popo Agie River join to form Bighorn River, the basin is more than 50 miles in width from north to south. It merges into a wide area of plains east of the Bighorn, but to the west it gradually narrows, and at the head of Wind River it contracts to a narrow valley which heads in the high divide separating the Wind River and Shoshone mountains. The altitudes are about 5,100 feet at the mouth of Wind River and 5,800 feet at the mouth of Crow Creek. North from Wind River the plains of the basin rise gradually to an altitude of about 6,000 feet at the foot of the central portion of the Owl Creek Mountains. The surface varies considerably, but east of Crow Creek rolling prairie predominates, interrupted by scattered areas of bad lands, such as are shown in Pl. X, *B*. These bad lands vary in extent from a few rods to half a mile in diameter. Some portions of the basin are sandy and districts of low sand dunes occur occasionally. Crow Creek flows in a rocky-sided valley 100 feet or more deep, and in the region to the west there is a succession of such valleys separated by ridges, in part with smooth surface and in part broken into bad lands. Wind River flows in a flat-bottomed valley which widens to the southeast, and Bighorn River has still wider bottom lands. From the bottom land there is a terraced rise from 30 to 100 feet to the adjoining uplands, but in places the river crosses the low flat to the foot of a cliff at the edge of the upland. Above the mouth of Crow Creek the bottom lands along Wind River are narrow and there are frequent high bad-land bluffs near the river. Along Muddy and Dry Creek valleys, near the foot of the mountains, there are extensive areas of high sandstone ridges rising out of the upland prairie above described.

U. S. GEOLOGICAL SURVEY

PLATE II.



MAP OF A PORTION OF WYOMING SHOWING AREA TREATED IN THIS REPORT

Scale of Miles

0 25 50 75 100

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The Owl Creek Mountains are a direct westward continuation of the Bridger Range, being separated from the latter by the great canyon of Bighorn River. The entire range is in reality a prolongation of the Bighorn Mountains, from which it is separated by a low saddle on Bridger Creek, 25 miles southeast of Thermopolis. To the west the Owl Creek Mountains merge into the Shoshone Mountains, which extend northward to and along the east side of the Yellowstone Park.

The Owl Creek Mountains vary from about 7,000 to 9,500 feet in altitude. They are about 7,000 feet high at the edge of the canyon of Bighorn River, which is a steep-sided trench 2,250 feet deep, cut across the axis of the range. The altitude continues to be about 7,000 feet westward from the canyon to the pass through which the road from Thermopolis to Lander crosses, but there drops rapidly to 6,244 feet, as indicated by a bench mark on the divide. To the west of this pass the range rises rapidly, and south of Embar it attains an altitude of somewhat over 9,000 feet. The highest point in this vicinity is Phlox Mountain, which, by barometric determination, is about 9,300 feet above sea level. This peak is a prominent knob of limestone, presenting high cliffs to the west and south. In this vicinity the southern slope of the mountain is steep, as there is a rapid fall to an altitude of about 6,500 feet. A short distance west of Phlox Mountain the range is crossed by a low pass traversed by the road from Anchor to Hollands, on the summit of which the altitude is 8,099 feet, as determined by United States Geological Survey levels. To the west of this pass the mountains consist of an irregular series of high limestone ridges varying from 8,300 to somewhat over 9,000 feet and merging into the Shoshone Mountains, in which the altitudes rise rapidly to considerably over 11,000 feet. The highest peaks of that range in this vicinity are the Washakie Needles, which reach 12,496 feet. Black Mountain, an outlying peak, has an altitude of 10,165 feet. South of the Owl Creek Mountains there are broad plains, in part bad lands, which extend to Wind River. On the north lies the Bighorn basin.

DRAINAGE.

The greater part of the run-off in the Owl Creek Mountains flows into Owl Creek, a branch of Bighorn River, which it joins 5 miles below Thermopolis. It flows along the north side of the range and has two principal forks—North Fork and South Fork—which rise in the south end of Shoshone Mountains, in the vicinity of the Washakie Needles. South Fork is much the larger stream. It passes through a deep canyon in the west end of the Owl Creek Mountains and then flows through a valley on the north side of the range. This stream receives the drainage of numerous tributaries on the north slopes, of which the largest is Mud Creek. Near the east end of the mountain the north slope is drained by Red Creek, which empties into Bighorn River 4 miles above Thermopolis. The south side of the Owl Creek Mountains is drained by Muddy Creek and its many branches on the east and by Dry, Red, and Crow creeks toward their western end. The three latter streams are affluents of Wind River. This river rises on the east slope of the Wind River Mountains and the south slope of the Shoshone Mountains. It flows southeastward to its confluence with Popo Agie River, with which it forms Bighorn River, a great stream flowing northeastward to the Yellowstone, a branch of the Missouri.

GEOLOGY.

DESCRIPTION OF THE ROCKS.

GENERAL FEATURES.

The Owl Creek Mountains are due to an anticlinal uplift of many thousand feet which has brought a thick series of Paleozoic and Mesozoic sedimentary rocks high above the adjoining plains. The crest of the uplift has been extensively eroded and in its central portion there appear at intervals areas of pre-Cambrian granites and associated rocks which underlie the sedimentary beds. The general stratigraphic features are very similar to those presented in the adjoining Bighorn[a] and Wind River uplifts, with certain local variations. Exposures of the rocks are extensive, especially in the many deep canyons of streams which flow out of the range at intervals. The structure presented on either side of the mountains is that of a monocline dipping to the south on the south slopes and to the north on the north slopes, but both of these sides have many variations in dip and are extensively corrugated by local flexures. The cross sections given in Pl. XI show the principal structural features. To the west the uplift passes beneath a thick series of overlapping volcanic and sedimentary rocks of Tertiary age, and in the plains to the south there is more or less extensive overlapping of the "Bridger" Tertiary beds. In the cross sections above referred to it will be seen that the pre-Tertiary formations consist of a series of thick sheets of sandstones, limestones, and shales, all conformable in structure, though lacking some members of the geologic succession. The following is a list of the formations exhibited in the uplift, with a generalized statement as to thickness, characteristics, and age:

Generalized section in the Owl Creek Mountains.

Formation.	Character.	Average thickness.	Age.
		Feet.	
Laramie formation ?	Gray sandstones and carbonaceous shales, with lignite deposits.	2,250	Upper Cretaceous (and Eocene ?).
Fox Hills sandstone?	Soft, massive buff sandstone, with harder, darker concretions.	225	Upper Cretaceous.
Pierre shale	Dark-gray shale, with concretions	1,000-2,600	Do.
Colorado formation	Gray shales; thin brown sandstones below; hard, fine gray sandstones and shales (Mowry beds) in middle part; concretions with *Prionocyclus*, etc., and massive buff sandstones at top.	1,000-1,300	Do.
Cloverly formation	Coarse, massive buff sandstone below, with purplish and gray shales and some sandstone above.	125	Upper and Lower Cretaceous (Dakota-Fuson-Lakota).
Morrison formation	Massive shale, greenish gray, buff, and maroon, with thin sandstones.	200	Lower Cretaceous (?).
Sundance formation	Soft sandstones, overlain by greenish-gray shales; several hard fossiliferous layers near top and bottom.	200	Jurassic.
Chugwater formation	Red shales and soft sandstone; thin limestone layers near top and bottom and gypsum deposits near top.	800	Triassic (?) and Permian.
Embar formation	Gray limestone, with cherty beds	250	Carboniferous (Pennsylvanian).
Tensleep sandstone	Massive buff to gray sandstone	200	Do.
Amsden formation	Red shales at base, overlain by fine-grained white limestone; sandstones and cherty limestone near top.	250	Carboniferous (Pennsylvanian and Mississippian ?).
Madison limestone	Light-colored limestones, very massive near top.	550	Carboniferous (Mississippian).
Bighorn limestone	Hard, massive limestones, with irregular streaks of silica.	40-150	Ordovician.
Deadwood formation	Slabby limestones with flat-pebble limestone conglomerates, 0-100 feet. Green shale with limestone member near base, 400-500 feet. Sandy shales with sandstone member near base, 200-300 feet.	900	Middle Cambrian.
	Massive, brown sandstones, 50-100 feet.		
Granite	Gray and red of various kinds, penetrated by diabase and other dikes.		Archean or Algonkian.

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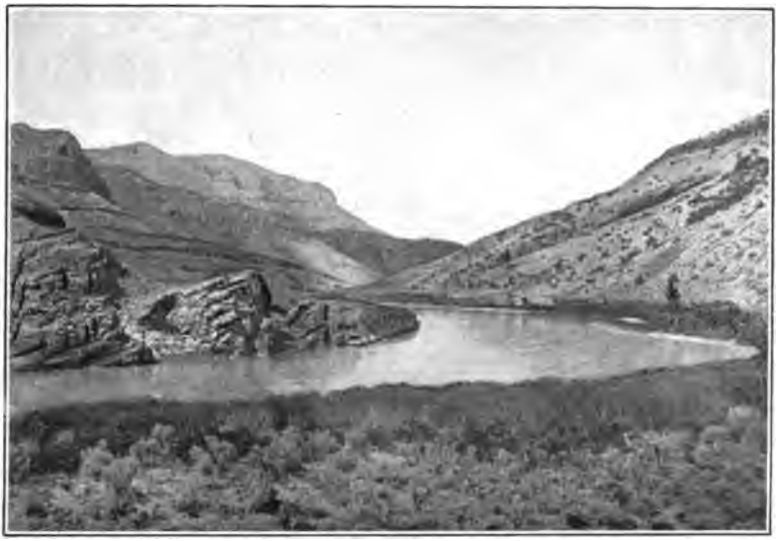
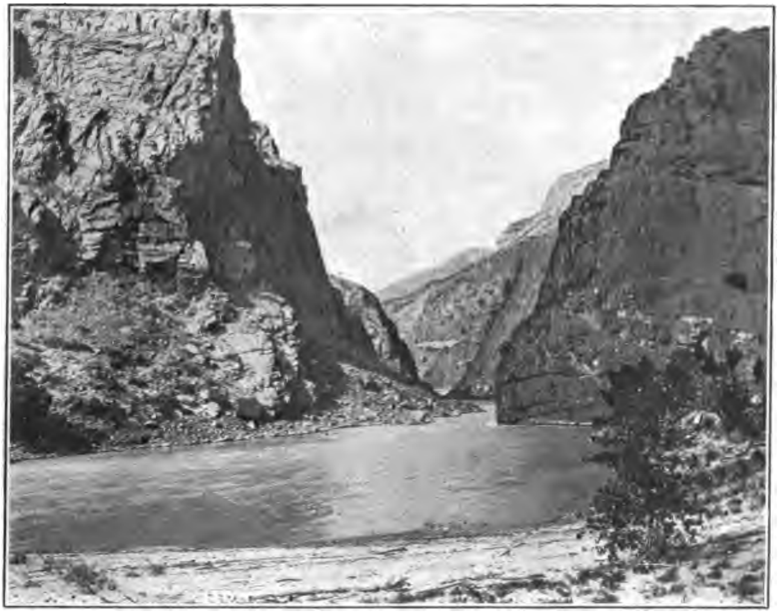
[a] The geology of the Bighorn Mountains is described by N. H. Darton in Professional Paper No. 51, U. S. Geol. Survey, now in press.



A. VIEW NORTHWARD IN UPPER CANYON OF BIGHORN RIVER, SHOWING DEADWOOD, BIGHORN, MADISON, AND OVERLYING FORMATIONS.

Granite at fault in foreground. D, Black schist; B, Bighorn limestone; L, Middle limestone in Deadwood formation; M, Madison limestone; A, Amsden formation.



B. VIEW NORTHWARD INTO NARROWS OF UPPER CANYON OF BIGHORN RIVER, AT EAST END OF OWL CREEK MOUNTAINS.

In the foreground are diorites brought up by a great fault. In the distance are overlying formations to Tensleep sandstone

The granites are mostly red and massive, but associated with them are extensive bodies of dark-colored, basic rocks which, with the granite, constituted a floor for sediments of middle Cambrian age. These Cambrian rocks are sandstones, shales, and limestones about 900 feet thick and apparently do not include sediments of upper Cambrian age. The Ordovician is represented by massive limestone of Trenton age, while the uppermost Ordovician and the Silurian and Devonian are absent. The Carboniferous presents about 1,250 feet of beds, of which the lower half is Mississippian and the upper half Pennsylvanian. The top member is a limestone (Embar), which often constitutes long slopes on the mountain sides. Next follow the "Red Beds," which extend along the foot of the mountain, as in most other uplifts in the Rocky Mountain province. They attain a thickness of about 800 feet and perhaps are all of Permian age, though possibly the Triassic may be represented by the uppermost beds. The marine Jurassic which follows is similar to that of the Black Hills and Bighorn Mountains, and contains an abundant upper Jurassic fauna It is overlain by the Morrison shales and sandstone, only about 200 feet thick but presenting the characteristics which are so general throughout the Rocky Mountain province.

Representatives of the "Dakota" sandstone appear in the uplift, but with greatly diminished development as compared with the Black Hills and other regions to the south. As in the Bighorn Mountains, the basal, hard sandstone, supposed to represent the Lakota formation, is the most conspicuous feature. The great series of upper Cretaceous shales attains a thickness of somewhat over 2,000 feet in the lowlands north of the Owl Creek Mountains—very much less than in the region adjoining the Bighorn uplift on the east. At the base is the Benton formation, which, as in the Bighorn uplift, does not present the characteristic middle limestone (Greenhorn) which is so prominent in the Black Hills uplift, eastern Colorado, and farther east. The Niobrara presents but little evidence of the chalky element which is so characteristic farther east and south, and also lacks the characteristic fossil *Ostrea congesta.* Its presence is indicated, however, by the apparently unbroken sedimentation from the Benton to the Pierre. At or near this horizon occurs a prominent bed of sandstone, containing large numbers of fossils which may represent a special Niobrara fauna. The Pierre shale, with a thickness of 1,000 feet on the north and somewhat over 2,000 feet on the south, presents the usual monotonous succession of gray shales with fossil-bearing concretions. It is terminated by a sandstone supposed to represent the Fox Hills, and this in turn is succeeded by a great development of sandstones and carbonaceous shales supposed to be of Laramie age. The Tertiary is represented by the "Bridger" deposits in the plains south of the mountains, with outliers overlapping onto the mountain slopes at some points, and to the northwest by a great succession of volcanic and sedimentary rocks constituting the Shoshone Mountains. The Quaternary deposits consist of high terraces and old fans along the lower slopes of the mountains and alluvial plains along the streams, which merge into flood plains of the present period. But little evidence of glaciation has been found. The hot springs at Thermopolis are depositing travertine along the banks of Bighorn River, and deposits of this material of considerable antiquity cap some of the buttes north of the town.

PRE-CAMBRIAN ROCKS.

GENERAL RELATIONS.

The largest exposure of granites and associated rocks in the central portion of the Owl Creek Mountains occupies an area of about 100 square miles. Its form is elliptical, about 5 miles wide at its greatest breadth and extending about 25 miles from northwest to southeast. It constitutes a prominent ridge, or series of ridges, bordered by slopes and knobs of the Deadwood sandstone and overlying rocks. At a few points the granite is bounded by faults which bring it into contact with various formations, even as high as the upper portion of the Pierre shale at one point on the south side of the range. The next largest area of pre-Cambrian rocks is exposed in the slopes south and west of Phlox Mountain, and other exposures appear in the deep canyons of Crow Creek, Bighorn River, and near the heads of Dry Creek and West Fork of Muddy Creek. The principal exposure in the canyon of Bighorn River is in the vicinity of a great fault by which all of the beds are raised about 1,000 feet, as shown in section 1, Pl. XI. Just north of this fault the pre-Cambrian rocks rise in cliffs several hundred feet high, as shown in Pl. III, *B*.

CHARACTER.

The pre-Cambrian rocks of the Owl Creek Mountains are in most respects similar to those of the Bighorn uplift. Coarse-grained red granites predominate, but these are intersected by extensive bodies of dark-colored basic rocks. No detailed examination was made of the crystalline-rock area.

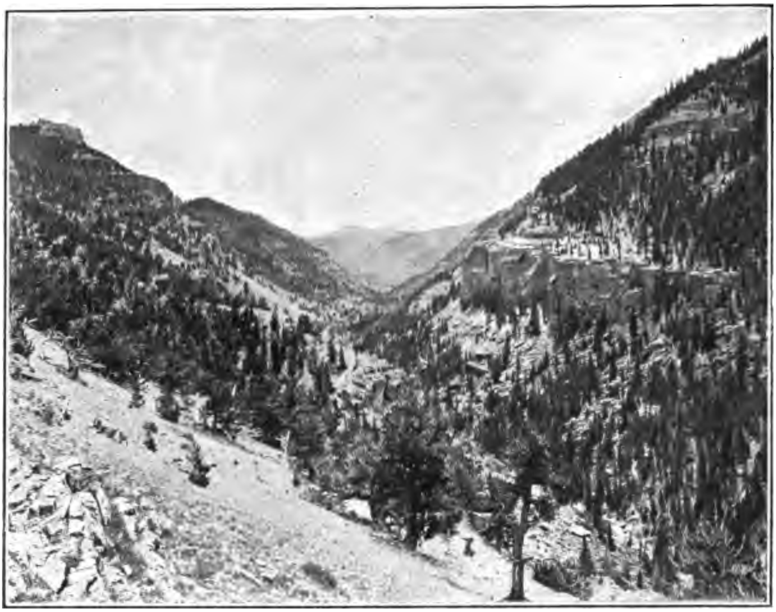
CAMBRIAN SYSTEM.

DEADWOOD FORMATION.

General relations.—The Deadwood formation consists of sandstones, shales, and limestones, and has an average thickness of 900 feet. Its outcrop area encircles the central granite areas, extends along a portion of the canyon of South Fork of Owl Creek above Anchor, and along the canyon of Bighorn River in the southeastern portion of the territory covered by this report. It is cut out by faults at a few points along the center of the uplift and in the vicinity of West Fork of Muddy Creek. There are extensive exposures in the slopes below Phlox Mountain and along the various head branches of Muddy Creek, as well as in and near the canyon of Bighorn River and the slopes adjoining the canyon of Crow Creek. The outcrop zone varies in width from a few hundred yards where the dips are steep to a mile or more where the strata are less steeply inclined.

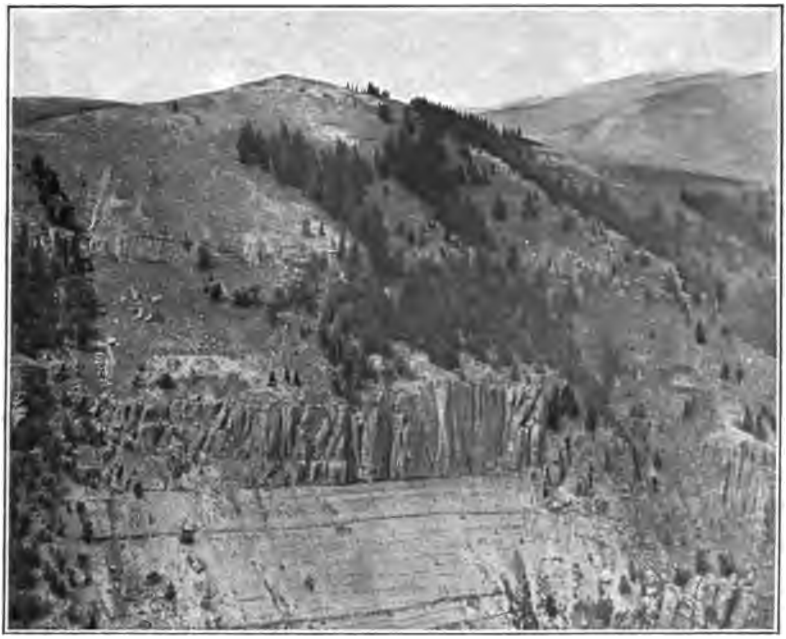
Rocks.—The succession of beds in the Deadwood formation is nearly uniform over the entire area of the Bighorn and Owl Creek uplifts. At the base there are usually coarse-grained reddish-brown sandstones, which are of such hardness that they give rise to a ridge on the slopes or a shelf in the canyon walls. These sandstones lie on a remarkably smooth surface of granite, evidently reduced to a plain by earlier Cambrian erosion. At the base of the formation the lower sandstone is usually conglomeratic, containing quartz pebbles, mostly of small size. The sandstone varies considerably in thickness and hardness, but it has not been observed to be less than 50 feet at any place, and in some localities it is 100 feet thick. Next above are sandy shales and thin-bedded sandstones 200 to 300 feet thick, with a prominent bed of sandstone in the lower portion.

In the vicinity of Bighorn Canyon this sandstone layer, which is 50 to 60 feet thick, is of a rich reddish-brown color. The medial portion of the formation consists of 400 feet or more of soft greenish-gray shales, with a prominent bed of gray to buff limestone in its lower part. This member is usually 50 feet thick and consists partly of a limestone conglomerate with flat limestone pebbles. Its presence is generally marked by a distinct ledge in all the outcrops. (See L, Pl. III, *A*.) Southwest of Embar it is 30 feet thick and 300 feet above the base of the formation. At the head of Muddy Creek it is 40 feet thick and underlain by a somewhat thicker mass of sediments. The top member of the Deadwood formation consists of slabby limestone over 100 feet thick at most localities, but apparently either very thin or absent in Owl Creek Canyon. (See Pl. IV, *B*.) The rock is mostly gray, but in part flesh-colored to brownish buff. It contains frequent layers and masses of a peculiar conglomerate that is highly characteristic, consisting of flat limestone pebbles, often inter-



A. CANYON OF OWL CREEK, 10 MILES SOUTHEAST OF WASHAKIE NEEDLES.

Looking southeast. Shows high cliff of Bighorn limestone (B) with Madison limestone (M) above. Hill of Amsden formation in the distance.



B. CONTACT OF BIGHORN LIMESTONE ON DEADWOOD SHALES IN CANYON OF OWL CREEK, 10 MILES SOUTHEAST OF WASHAKIE NEEDLES.

Looking west. The upper slopes and ledges are Madison limestone. In the distance to right are sedimentary and volcanic rocks of Tertiary age.

mingled with thin, twisted, and broken layers of limestone in a matrix of fine limestone and shale material. Many of the pebbles are so thickly covered with grains of glauconite that they appear to be green, but inside they are gray or pinkish, similar to the associated beds. They are clearly intraformational conglomerates.

Fossils.—Fossils occur at various horizons in the Deadwood formation. They are of middle Cambrian age and *Dicelamus politus* and *Ptychoparia owenii* are the principal forms. The former are small oval shells which occur in great abundance in the middle sandstones and in the limestone layers in the shales, as well as in the upper limestone series. The *Ptychoparia* is a trilobite which occurs often in great abundance in the basal sandstone.

ORDOVICIAN SYSTEM.

BIGHORN LIMESTONE.

General relations.—The Bighorn limestone, which is so conspicuous in the northern portion of the Bighorn uplift, appears to be continuous in the Owl Creek Mountains, but of greatly diminished thickness. To the east it is about 40 feet thick, while in the vicinity of Phlox Mountain and Owl Creek Canyon it is over 150 feet thick and in the vicinity of Crow Creek about 100 feet. The formation outcrops continuously around the higher central area of the Owl Creek uplift and westward along South Fork of Owl Creek to a point 3 miles west of longitude 109°. It outcrops again on the slopes adjoining Crow Creek Canyon and the upper portion of West Fork of Muddy Creek and in Bighorn Canyon. The most prominent exposures are in the great south and west facing escarpment of Phlox Mountain, where it appears in cliffs nearly 150 feet high. Good exposures of considerable extent also appear in Owl Creek Canyon and at points on the headwaters of Mud Creek.

Rocks.—The formation consists almost entirely of a massive limestone, usually of light-buff color, somewhat darker when weathered, filled with a coarse mat of irregular siliceous masses, mostly from one-half to 1 inch in diameter. On weathering this siliceous material stands out half an inch or more on the rock surface as a ragged network, the purer rock between having been dissolved. This feature and the very massive bedding are characteristic. Owing to the softness of the underlying Deadwood shales and the hard, massive nature of the Bighorn limestone, the latter usually forms high cliffs with a talus of huge blocks of limestone on the slopes below. In the canyons the limestone gives rise to steep walls, presenting almost continuous outcrops of the formation. This feature is strikingly exhibited in Phlox Mountain.

In Owl Creek Canyon the massive limestone is overlain by 20 feet of white broken limestone, capped by a 20-foot massive bed similar to the thick limestone below, while at the top of the formation there are a few feet of sandstone and shale. In places these upper beds weather to a reddish tint, strongly suggestive of the member of Richmond age, which occurs in the northern portion of the Bighorn uplift. The appearance of one of the most prominent outcrops in the Owl Creek Canyon is shown in Pl. IV, and some ledges of the formation in Bighorn Canyon are shown in Pl. III, *A*. In Pl. IV, *B*, is shown the contact of the massive limestone with the Deadwood shales.

Fossils and age.—The Bighorn limestone in the Owl Creek uplift appears to contain but very few fossils. Fragments of Maclurina and corals were observed at a number of points, similar to those which occur in the Bighorn uplift. In that uplift the formation yields fossils which are regarded as lower Galena-Trenton, and there is also an upper series containing a typical Richmond fauna. At the top of the Bighorn limestone there is a hiatus representing a part of Ordovician and all of Silurian and Devonian time, but, so far as observed, there is no marked exhibition of unconformity at the base of the overlying Madison limestone.

CARBONIFEROUS SYSTEM.

MADISON LIMESTONE.

Relations and character.—The thick series of rocks known as the Madison limestone is extensively exhibited in the higher portion of the Owl Creek uplift and in and near the canyon of Bighorn River. Ordinarily it rises in a prominent flanking ridge, or gives rise to steep slopes and numerous cliffs in the canyon walls. It averages from 500 to 600 feet in thickness and is uniform in character throughout, consisting of moderately thick-bedded gray limestones in its lower portion and an upper member of massive light-colored limestone which weathers to a light dove color. This upper member is usually cavernous and often weathers in pinnacles and castellated forms. Extensive and complete exposures appear in the canyon of Bighorn River and on the adjoining slopes and at intervals in the higher uplift to the west, notably in the vicinity of Phlox Mountain, Owl Creek Canyon, and Black Mountain. The widest areas are in the slopes adjoining the canyon of South Fork of Owl Creek and those extending east and south of Phlox Mountain. Some features of the Madison limestone are shown in Pls. III and IV. The formation is cut out by faults at a few points near the head of Red Creek and of North Fork of Muddy Creek.

Fossils and correlation.—Fossils occur abundantly at various horizons in the Madison limestone, especially in its middle and upper portions. *Spirifera centronatus*, *Seminula humilis*, and *Chonetes loganensis* are the principal forms, and these indicate that the formation is of Mississippian age, equivalent to the Madison limestone of Montana and the Pahasapa limestone of the Black Hills.

AMSDEN FORMATION.

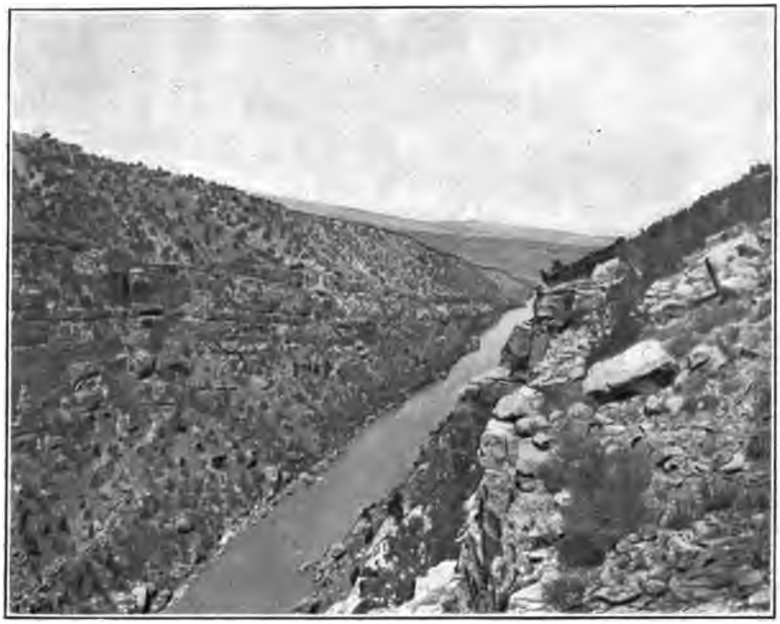
General relations.—Overlying the Madison limestone is a series of red shales, limestones, sandstones, and cherty beds, which has been designated the Amsden formation. Its average thickness is between 200 and 250 feet. Its outcrop extends along the middle slopes on both sides of the mountains, except at a few localities where it is cut out by faults or overlapped by younger formations. It surmounts the cliffs of Madison limestone in Bighorn Canyon and along the south front of the mountain westward nearly to the pass where the Lander road crosses the range. It also appears at many localities adjoining the higher central portion of the uplift and at intervals farther west. An outlying area caps the high ridge south of the canyon of South Fork of Owl Creek, and the formation is a prominent feature on the east slope of Black Mountain and the ridge next north.

Rocks.—Throughout the area there is at or near the base of the formation a deposit of red shale. This usually lies directly on the massive upper member of the Madison formation, but locally, to the west of Anchor, it is separated by a bed of massive gray sandstone. The red shales are usually about 50 feet thick and they contain near the top one or two thin beds of very fine grained white limestone. The middle and upper portions of the formation consist mainly of sandy beds, in places containing considerable lime at some horizons. Toward the top there are usually extensive deposits of chert, which weathers out and accumulates on the slopes.

Age.—Fossils are exceedingly rare in the Amsden formation in this area, but in the Bighorn uplift to the east the upper beds have yielded a number of species typical of the Pennsylvanian series. At certain localities a few forms of supposed Mississippian age have also been observed in the limestones of the basal red shales, so that apparently the formation comprises part of both divisions of the Carboniferous.

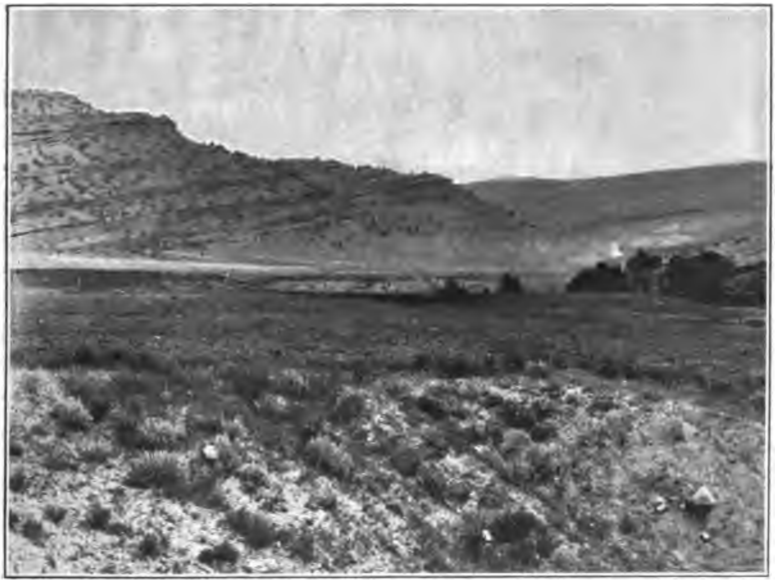
TENSLEEP SANDSTONE.

Relations.—The thick sheet of the Tensleep sandstone extends along the sides of the Owl Creek uplift, with an outcrop usually marked by a ridge of considerable prominence. Its thickness averages slightly over 200 feet, with few local variations.



A. NORTH END OF UPPER CANYON OF BIGHORN RIVER SOUTH OF THERMOPOLIS, WYO.

Shows dip slope of Embar limestone and high cliffs of Tensleep sandstone.



B. THE "RED WALL" OF RED CREEK, 8 MILES SOUTHWEST OF THERMOPOLIS, WYO.

Looking east. Chugwater Red Beds and upper portion of Embar limestone on extreme right.

In the east end of the range it outcrops at or near the top of the mountain and extends far northward in the canyon of Bighorn River. A characteristic view of the formation near the north end of this canyon, south of Thermopolis, is shown in Pl. V, *A*. In the low divide, where the Lander road crosses the mountains, the formation presents a complete arch, constituting the summit. To the west, however, in the area of increased uplift, the sandstone extends along the flanks of the mountain in a line of knobs and ridges considerably lower in altitude than those of the underlying formations. There are extensive exposures on the slopes south of Middle Fork of Owl Creek, in the anticlinal ridge west of Hollands and on the east slope of Black Mountain.

Rocks.—The predominant rock is white to buff sandstone, in thick, massive beds, in greater part cross-bedded. At some localities the color is dark, especially on the weathered surfaces, a feature particularly noticeable near the Lander road and in the vicinity of Middle Fork of Owl Creek.

Age.—No fossils were observed in the Tensleep sandstone in the area to which this report relates, but in the Bighorn uplift a number of species characteristic of the Pennsylvanian series were obtained.

EMBAR FORMATION.

Relations and character.—Throughout the Owl Creek uplift there is a prominent series of limestone and chert beds lying between the Tensleep sandstone and the Chugwater red beds. It has been designated the "Embar" formation, from Embar post-office and ranch on Owl Creek. The formation has an average thickness of between 200 and 250 feet, and it usually gives rise to long dip slopes on the flanks of the mountains. The most prominent exposure is in the great dip slope of the high range a few miles south of Thermopolis, where the formation constitutes the surface for many square miles on either side of the canyon of Bighorn River and south of Red Creek. These long slopes are due mainly to a bed of limestone about 50 feet thick, which constitutes the greater part of the upper member of the formation throughout its course. (See Pl. XIII, *B.*) This limestone is underlain by 100 feet or more of cherty shales and overlain by yellowish sandstones and cherty beds.

The formation is extensively exhibited along the mountain slopes to the west, especially on some of the ridges due to anticlines branching from the main uplift. Two of these, northwest and west of Hollands, are especially notable as exhibiting wide areas of the formation. Another appears east of Anchor, crossed by South Fork of Owl Creek in a deep gorge, and there is another extending southeast of Embar. The northwesternmost exposure is in a prominent knob near the head of Middle Fork of Owl Creek, north of which begins the overlap of the Tertiary volcanic series. It appears in the more elevated portion of the anticline which passes through Thermopolis, in a small but characteristic outcrop of limestone and cherty ridges. At a few points along the sides of the higher portion of the central uplift the formation is cut out by faults for a short distance.

An outcrop of the formation in the canyon walls south of Thermopolis is shown in Pl. V, *A*. At this locality the limestone is 50 feet thick. It is a gray rock, of moderately massive bedding and of considerable hardness. This member here lies on about 100 feet of shale, partly limy, filled with oval concretions of chert mostly from 1 to 2 inches in diameter. Next below are alternations of limestone and shale, 25 feet or more in thickness, lying on a thin deposit of sandstone breccia, which in turn lies on Tensleep sandstone. At the foot of the mountain slope the limestone is seen to pass under yellowish sandy beds containing a few thin, impure layers of limestone, in all from from 50 to 60 feet thick. In the vicinity of North Fork of Muddy Creek the thickness of the formation is about 250 feet. The limestone member, here about 50 feet thick, lies nearly 100 feet below the top, and there is a thinner limestone at a higher horizon. The other material is shale, containing a large amount of nodular chert. Toward the top the beds are sandy and in most places of a bright yellow color. On the south slope of the anticline, 6 miles due west of Holland's ranch, the following section of the formation was measured:

Section of Embar limestone 6 miles west of Holland's ranch.

	Feet.
Compact gray sandstone, weathering brown, merging downward into brownish-gray and yellowish soft sandstone	50
Light-colored massive limestone	30
Nodular dark-colored limestone, in part cherty	80
Dark-gray fossiliferous sandstone	4
Light buff-colored soft sandstone, with layers of limestone, lying on Tensleep sandstone	60

In the vicinity of Embar the limestone member is 50 feet thick. In the region near Anchor post-office the top member of the formation consists of 20 feet of soft buff sandstone, which lies immediately on the massive limestone. On Dry Creek, 6 miles northeast of Black Mountain, the formation is very much thicker than observed elsewhere. At the base are nearly 200 feet of sandstones and limestones. The characteristic medial limestone is 30 feet thick and highly fossiliferous. It is overlain by over 200 feet of slabby brown sandstones, with some layers of buff soft sandstone, extending to the base of the Chugwater red beds.

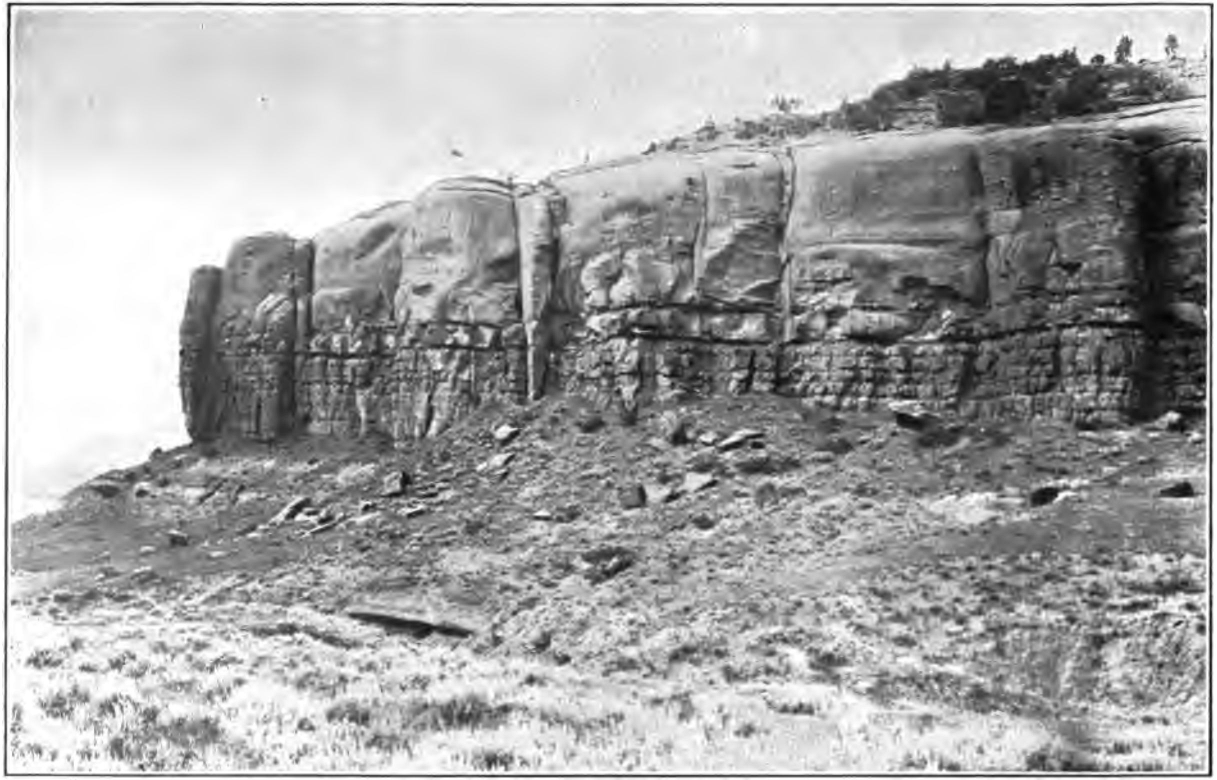
Fossils and age.—The limestone of the Embar formation contains large numbers of fossils, especially in the walls of Bighorn Canyon south of Thermopolis, but so far as observed they consist only of one mollusk, identified by Dr. G. H. Girty as *Spiriferina pulchra*. This form is believed to characterize a horizon just below the so-called Permo-Carboniferous of the Wasatch Mountain region, and, as Doctor Girty correlates the latter with the Permian of the Grand Canyon section, the occurrence of these fossils in the Embar limestone suggests that this formation is equivalent to the upper Aubrey limestone of northern Arizona. A fenestelloid which could not be determined specifically also occurs in this limestone.

TRIASSIC SYSTEM (?).

CHUGWATER FORMATION.

General relations.—Extending along the base of the steeper portions of the slopes of the Owl Creek Mountains is a series of red beds which has been designated the Chugwater formation. The rocks are mainly soft, massive, red, fine-grained sandstones merging into red shale; extensive gypsum deposits and a few thin limestone beds are also included. The brilliant red color renders the formation a conspicuous feature in most portions of the outcrop area, especially as the rocks usually rise in a high red wall or in prominent steep-sided buttes.

The outcrop is mostly narrow and partly discontinuous on the south side of the mountain, but on the north side there are several wide areas. The most notable of these extends along Red Creek and its western branches. Another extensive area crosses the valley of South Fork of Owl Creek above Embar, presenting long lines of high red walls. Exposures of considerable width extend along the south side from North Fork of Muddy Creek to and beyond Hollands, while along Red Creek east of Black Mountain there are high red walls and long slopes of Chugwater red beds. The anticline which passes through Thermopolis exhibits the formation in a long area, which is nearly 3 miles wide where crossed by Bighorn River and Owl Creek. A small outcrop of the upper beds of the formation appears in the anticline on the divide between Dry and Muddy creeks, a short distance north of latitude 43° 30′. A characteristic view of the high red wall of this formation, on Red Creek, is shown in Pl. V, *B*. The thickness of the formation averages about 800 feet.



MASSIVE SANDSTONE IN MIDDLE OF CHUGWATER RED BEDS, ON BIGHORN RIVER, 3 MILES SOUTH OF THERMOPOLIS, WYO.

A characteristic member of the Chugwater formation.

Rocks.—The general character of the Chugwater deposits does not vary greatly in different portions of the uplift. Toward the top and bottom red shales predominate, while in the middle soft sandstones and alternations of sandstones and shales are the principal features. Near the base there is usually a thin bed of purplish-gray limestone from 18 inches to 3 feet thick, and in some portions of the area two such limestones appear. A widespread sheet of limestone about 2 feet thick lies from 100 to 150 feet below the top of the formation. This bed is especially notable on the east bank of Bighorn River, 3 miles north of Thermopolis, where it has yielded an abundance of fossil molluscan remains. At a few localities, especially near the head of Mud Creek and at the south end of Bighorn Canyon, the upper portion of the formation contains a number of beds of gray to buff sandstone. To the west there is, in the upper portion of the formation, a prominent bed of orange-colored massive sandstone overlain by a thick bed of gypsum, the top of which is about 100 feet below the top of the formation. This gypsum bed has a thickness of 30 feet south of Embar and on Red Creek southeast of Thermopolis, and 40 feet in extensive exposures in the vicinity of Hollands. Through the greater portion of its extent there is, near the middle of the formation, a massive bed of pale-red sandstone of fine, uniform grain, of which a characteristic outcrop is shown in Pl. VI.

Fossils and age.—Fossils have been found at various horizons in limestones in the Chugwater red beds, but they do not afford conclusive evidence as to the age of the formation. Some of the lower limestones in portions of the Bighorn and other uplifts have yielded remains which are believed to be of Permian age, in the sense in which the term Permian is used in the Mississippi Valley. The fossils which occur abundantly in the limestone 150 feet below the top of the formation, on the east bank of Bighorn River, 3 miles below Thermopolis, have been determined by G. H. Girty, and he reports that the principal species is *Natica lelia*, which has usually been considered diagnostic of the Triassic in some portions of the West, but probably is older. Apparently there are also Bakewellia and probably Phleurophorus, but the remains are not sufficiently distinct for satisfactory determination. An Aviculipecten occurs, resembling *A. curticardinalis*, a small pectinoid of a type very characteristic of the Permo-Carboniferous of Utah. Doctor Girty is inclined to believe that the fauna indicates a position equivalent to the Permo-Carboniferous of the Wasatch Mountain section. The 150 feet of red shales and sandstones which overlie this limestone may possibly represent the Triassic in whole or in part, but there is no positive evidence.

JURASSIC SYSTEM.

SUNDANCE FORMATION.

General relations.—The representative of the marine Jurassic known as the Sundance formation consists of soft gray sandstones and green shales, having an average thickness of 200 feet. Its outcrop extends continuously along the north slope of the Owl Creek uplift to a point 4 miles west of Embar, where it passes beneath the Tertiary beds. On the south side it extends westward from North Fork of Muddy Creek to the flanks of Black Mountain, and also appears in small exposures near longitude 108° 30′, at the upper end of Bighorn Canyon, and in the two uplifts on the divide between Dry and Muddy creeks, near longitude 109°. The anticline which passes through Thermopolis exhibits a continuous exposure of the formation to and beyond Owl Creek. The most extensive outcrops are found in the divides between the headwaters of Red and Mud creeks, between Muddy Creek and Dry Creek, and between Dry Creek and Red Creek. The formation is also well exposed in the vicinity of Thermopolis and along the north side of the Thermopolis anticline.

Rocks.—The materials are sandstones and shales, presenting considerable variation in local stratigraphy. Toward the base there are always sandstones and the middle and upper beds are mainly shales, with more or less sandstone at the top. The shales are greenish or dark gray in color and contain limestone in concretions and thin layers, often highly fossiliferous. In the western portion of the uplift one of the sandstone beds in the upper portion of the formation is very hard and its outcrop is marked by a line of high but narrow ridges, which are especially prominent in the divide west of Dry Creek. In this vicinity 40 feet of the top beds are sandstones, of which the middle portion is very hard, and most of the beds are highly fossiliferous. In the vicinity of Embar and farther east the outcrop is also marked by a prominent ridge due to the hard dark-gray sandstones, 12 feet thick, of which a view is shown in Pl. VII, *B*. This bed is underlain by about 80 feet of shale and soft greenish-gray sandstones, of which some beds contain large numbers of *Gryphæa calceola*. The following section of the Sundance formation is exhibited on the south side of the anticline on Owl Creek, 7 miles northwest of Thermopolis:

Section of Sundance formation on Owl Creek, 7 miles northwest of Thermopolis, Wyo.

	Feet.
Green soft sandy shales and hard greenish fossiliferous sandstone in alternating layers	70
Gray sandstone	4
Green sandy clay	20
Gray calcareous sandstone	2
Dark greenish-gray sandy clay, with many belemnites	40
Greenish-gray sandstone, with occasional hard layers	30
Green sandy shale	20
Greenish-gray sandstone, thin bedded	4
Hard buff impure limestone, breaking into small rectangular blocks	2
Green sandy shale lying on "Red Beds"	2
	194

The exposure south of Bighorn Canyon is in the east bank of the river. Here the beds are about 250 feet thick, consisting of alternating layers of greenish-gray sandy shale and dark-gray fossiliferous sandstone, one ledge of which rises in a small but prominent ridge.

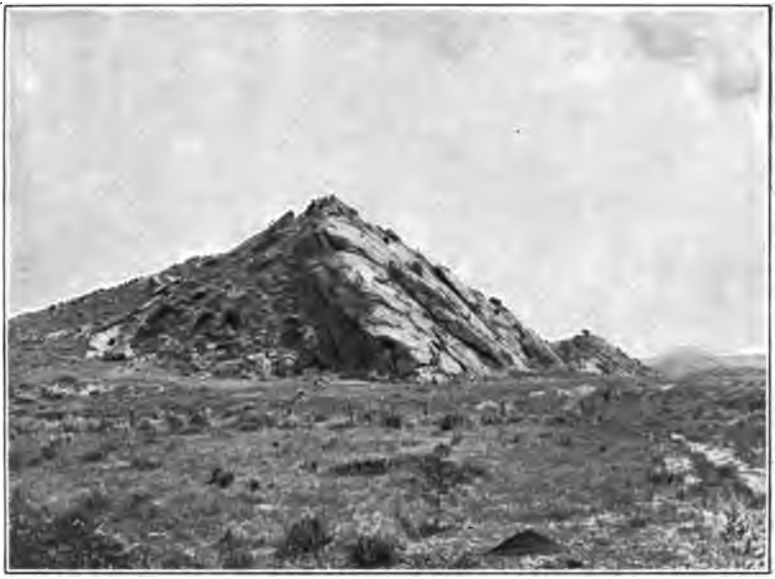
Fossils and equivalency.—The formation contains abundant fossils of middle and upper Jurassic age, and it is believed to be equivalent to the Sundance formation of the Black Hills region, where the name was first applied. The following fossils occur: *Belemnites densus*, *Gryphæa calceola* var. *nebrascensis*, *Campectonites bellistriatus*, *Eumicrotis curta*, *Trigonia elegantissima*, *T. americana*, *T. conradi*, *T. montanensis*, and *Pentacrinus asteriscus*.

CRETACEOUS SYSTEM.

MORRISON FORMATION.

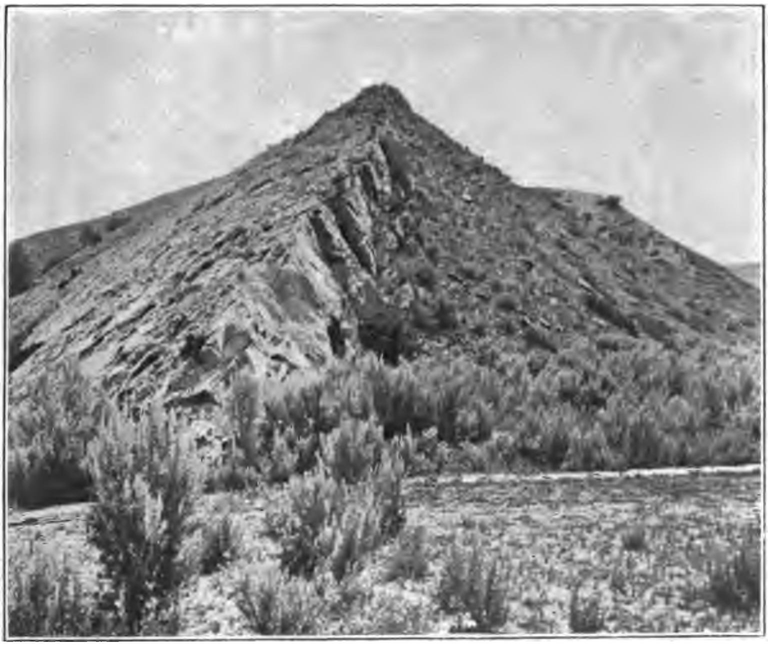
General relations.—The clays and soft sandstones of the Morrison formation extend along both sides of the Owl Creek uplift, but to the southeast and northwest they are extensively overlapped by Tertiary deposits. Frequent outcrops appear along the south side of the uplift from the head of North Fork of Muddy Creek westward and along the north slopes from the vicinity of Bighorn River to a point on the east side of range 100, where it passes under the Tertiary beds. It is also exhibited all around the Thermopolis uplift, in the anticlines in the divide between Muddy and Dry creeks, and in the center of a small anticline crossed by Owl Creek halfway between Middleton and Embar. There are numerous exposures in the vicinity of Thermopolis and farther north and at intervals along the mountain slopes in the area above described, especially along various branches of Mud Creek and in the divide between Dry and Red creeks. The thickness varies from 100 to 250 feet in greater part, in general diminishing slightly from east to west.

Rocks.—The predominating material is a mixture of clay and fine sand, or massive shale, of pale greenish-gray color, merging into deeper green, maroon, pink, and red. In the middle of the formation in this region there is usually a thick deposit of soft, fine-grained, greenish-gray sandstone 50 feet or more in thickness. This bed



A. HOGBACK OF CLOVERLY SANDSTONE ON EAST SIDE OF BIGHORN RIVER, THERMOPOLIS, WYO.

Looking east, on east slope of uplift.



B. HARD SANDSTONE MEMBER IN SUNDANCE FORMATION ON SOUTH FORK OF OWL CREEK, ONE-HALF MILE EAST OF EMBAR, WYO.

Looking east.

is well exhibited on the north slope of the anticline 4 miles northeast of Thermopolis, where the sandstone is 50 feet thick. It is here overlain by 40 feet or more of sandy shale, in part of maroon tint, over which is a 10-foot bed of loosely consolidated conglomerate with pebbles mostly of a very dark color. At the top of the formation are about 10 feet of highly carbonaceous and dirty buff shale. The basal beds here are reddish and greenish massive sandy shale.

On North Fork of Muddy Creek the formation is composed almost entirely of soft, fine-grained, white sandstone in very massive beds, lying on a small amount of light-colored shales of the usual character. Southeast of Embar this sandstone also predominates, merging downward into thin-bedded gray sandstones and more or less shale, which weathers to a buff color. In a small area exposed on the east side of Bighorn River, a short distance above the mouth of the canyon, the formation appears to be mostly of gray sandstone, but a thin bed of limestone is also included. In the very clear and extensive exposures on the east side of Red Creek, 3 miles east of the summit of Black Mountain, the formation is about 150 feet thick. At the top are soft, massive sandstones, mainly of buff color, but partly pink, lying on reddish and maroon clays. In the middle are 50 feet of red sandy clays, with a few soft sandstone layers from 6 inches to a foot thick, and some layers of purple clay. The lower 50 feet are massive sandy clays of gray and dirty maroon tints in alternating bands. This material lies on top of the Sundance sandstone, without any evidence of structural discordance.

Equivalency.—In the Owl Creek uplift the Morrison formation presents the same character and stratigraphic relations as in the Bighorn Mountains, Black Hills, and Rocky Mountain regions to the east and south. It contains fossil saurian remains, believed to be of the same fauna as those found in the other regions. Opinions are divided as to whether these are of late Jurassic or early Cretaceous age, but from stratigraphic evidence in other regions, the Morrison formation is here provisionally classed in the Cretaceous.

CLOVERLY FORMATION.

General relations.—The Cloverly formation consists of sandstone and sandy clay, representing the formation usually referred to as "Dakota" sandstone. Its thickness varies generally from 100 to 150 feet, and it lies on the Morrison clays throughout its extent. The outcrop zone extends continuously along the north side of the mountains to a point in range 100, where the Tertiary deposits overlap, and along the south side from the headwaters of North Fork of Muddy Creek to the Tertiary overlap a short distance beyond Red Creek. Small exposures appear on the south side of the mountains, near longitude 108° 30′, and more extensive ones encircle the anticlinal uplifts on the divide between Muddy and Dry creeks, near longitude 109°, and the uplift which passes through Thermopolis. Small exposures appear in the uplift cut by Owl Creek, near the junction of the two forks, and in a small anticline on Bighorn River, 5 miles northeast of Thermopolis. Owing to the low dips, the formation constitutes the long northern slopes of a series of hogback ridges rising along the north side of Buffalo Creek, crossing Bighorn River 2 miles south of Thermopolis, and extending westward nearly to the head of Mud Creek. The outcrop of the hard sandstone of the formation is also a prominent feature encircling the anticline which extends through Thermopolis. A characteristic outcrop a short distance east of that town is shown in Pl. VII, *A*.

Rocks.—The formation always consists of a lower member of hard, coarse gray to buff sandstone in massive beds and an upper member of clays or massive shales of purplish color containing thin beds of sandstone. Sometimes at the top of the formation there is a bed of gray or brown sandstone, which attains a thickness of 4 to 8 feet locally. In the Mud Creek region the basal sandstone is 30 feet thick and the overlying beds are purple shales, with cherty concretions and thin layers of brown and buff sandstone. At the top are several layers of brown sandstone overlain by

Colorado shale. In the ridge north of Red Creek, a few miles southwest of Thermopolis, the formation is about 150 feet thick and presents three bodies of sandstone, with a considerable amount of purplish and gray shales and thin-bedded sandstones between the two upper members. In extensive exposures along Bighorn River north of Thermopolis the basal sandstone is 55 feet thick, consisting of 35 feet of hard, massive, light-gray sandstone, somewhat conglomeratic at the base, overlain by 20 feet of softer buff sandstone. The middle member, 30 feet thick, consists mostly of purplish shale, while at the top are about 6 feet of slabby dark-buff sandstone which weathers to a brown tint. The presence of conglomerate in the lower portion of the basal member is a general feature. In the slopes southeast of Embar the formation is over 200 feet thick and consists of two prominent masses of sandstone, the lower one the larger, separated by purplish clays and shales, with thin-bedded sandstone.

On Red Creek, 3 miles southeast of the summit of Black Mountain, the formation exhibits the usual tripartite series, having at the base 30 feet of hard white to gray sandstone, massive and in part cross-bedded, 100 feet of medial clays, and at the top about 10 feet of hard slabby to massive sandstones which weather to a dark color, and are immediately overlain by the black shales of the Colorado. The clays between the two sandstones are of strong purple color for 30 feet or more near the top, becoming paler below. In the middle they are pale greenish gray, and contain a few layers of fine gray sandstone of white, buff, and greenish tints and several bands of calcareous and cherty nodules, the latter being especially abundant in the lower third of this medial member. This occurrence of cherty nodules is general in much of the region adjoining the Owl Creek Mountains.

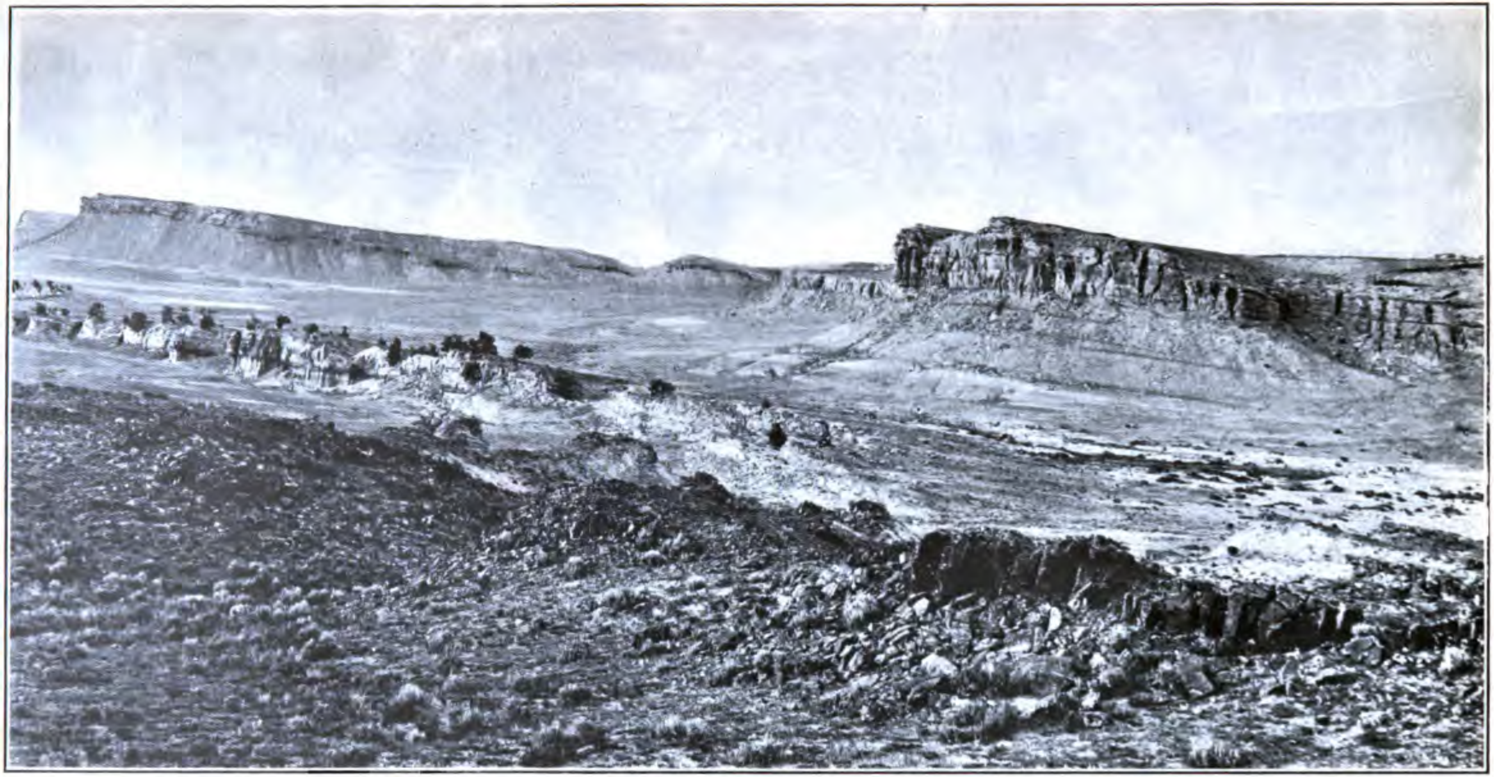
On North Fork of Muddy Creek the basal sandstone series is of particularly light color, and contains in its lower portion a thick mass of white conglomerate.

Correlation.—No fossils have been discovered in the formation, but its physical features are such that it may be readily correlated with the deposits at the same horizons in other regions. The basal sandstone is probably equivalent to the Lakota sandstone of the Black Hills, and the overlying purple shales are similar in character to the Fuson formation of that region. Both of these are of lower Cretaceous age. The top sandstone probably represents the Dakota.

COLORADO FORMATION.

General relations.—In the Colorado formation begin the thick deposits of black shales which characterize a large portion of the middle Cretaceous. Its average thickness is about 1,000 feet. Included in the black shales which constitute the greater part of the formation are certain sandstone layers, especially in its upper portion, and a series of hard shales which weather to a light-gray color in its middle portion. The outcrop zone extends along the foot of the mountain and the outlying uplifts to the north and southwest. There are broad areas in the slopes and divide between Mud and Owl creeks and in Owl Creek Valley east of Embar. A zone of considerable width surrounds the Thermopolis uplift and the anticlines on the south side of the main uplift near longitude 109°. A small area lies close against the mountain slopes in a peculiar rectangular syncline at the head of Mud Creek.

Rocks.—The stratigraphic succession of the formation is uniform throughout. The lowest beds are several hundred feet of dark-colored shale, usually containing toward the base a deposit of sandstone from 2 to 20 feet thick. This is capped by the Mowry beds, consisting of from 100 to 150 feet of hard shales and thin-bedded, fine-grained sandstones of dark-gray color, which on exposure weather to a very characteristic light gray. These rocks are especially characterized by the occurrence of large numbers of fish scales in nearly every bed. They are often so abundant as to number from 5 to 10 on a surface 6 inches square. Owing to their hardness, the beds give rise to round-topped ridges of considerable prominence. These are conspicuous



SANDSTONE AT TOP OF THE COLORADO FORMATION, 3 MILES SOUTHWEST OF HOLLAND'S RANCH.

Owl Creek Mountains in the distance; a lower sandstone of Colorado formation in the foreground.

features along the north side of the valley of Mud Creek, in the syncline east and west of Thermopolis, along the north side of the anticline north of Thermopolis, and encircling the anticlines and synclines in the vicinity of longitude 109° on the south side of the Owl Creek uplift.

Next above are dark-gray shales 400 feet or more in thickness, containing toward the top one or two prominent beds of gray to buff sandstone, usually sufficiently hard to constitute ridges, mesas, or escarpments. This sandstone member often attains a thickness of 40 feet. Toward the top of the formation there are from 100 to 150 feet of dark shales, which contain near their upper portion lens-shaped brown to buff concretions mostly from 2 to 3 feet in diameter, often containing *Prionocyclus woolgari*, a form highly characteristic of the uppermost portion of the Benton in most regions. This fossil is an ammonite with nodes on its whorls and often attains a diameter of from 14 to 20 inches. The following section measured on Red Creek, 3 miles east of Black Mountain, illustrates the principal features in the stratigraphy of the Colorado formation in the western portion of the Owl Creek Range:

Section of Colorado formation on Red Creek, 3 miles east of Black Mountain.

	Feet.
Gray massive sandstones, mostly hard; many fossils	15
Dark shale with sandstone beds	200
Light-gray sandy shale, weathering light buff	40
Coarse buff sandstone	10
Dark shale	5
Dark shale with several layers of hard buff sandstone from 3 to 18 feet thick	200
Buff sandstone	3
Black shale	50
Light-gray sandstone, massive and moderately hard	25
Brown and gray hard fine-grained sandstone, slabby	25
Hard gray shales and thin-bedded, fine-grained sandstones with fish scales (Mowry beds)	250
Gray shales, containing near the middle 10 feet of hard buff sandstone in two bodies separated by 20 feet of sandy shale	700
Sandy shale and thin sandstone, brown, olive-green, and rust color, slabby	125
	1,648

The 40-foot stratum of light-gray sandy shale weathers to a light-buff color, somewhat suggestive of the Niobrara formation in other regions.

Top sandstone.—The top sandstone referred to above, possibly together with a portion of the adjoining shales, may represent the Niobrara formation, comprising the strata down to and including the light-gray sandy shale which weathers to a light-buff color. This fossiliferous sandstone varies in thickness from 5 to 25 feet and is a persistent feature in the stratigraphy along both slopes of the Owl Creek uplift and the western portion of the Bighorn uplift, though to the east it has not been found to be fossiliferous. It is usually hard and gives rise to a ridge of considerable prominence, reaching moderate elevations above the adjoining shale slopes. It is a conspicuous feature in Owl Creek Valley for several miles east and west of Middleton and in the synclinal basins on the south side of the uplift near Dry and Muddy creeks. On the east side of the syncline east of Dry Creek the beds stand nearly vertical, and this sandstone outcrops in a wall from 5 to 30 feet high, extending for several miles northwest and southeast. In this vicinity and farther west toward Red Creek the sandstone is highly fossiliferous, containing the following species, which have been identified by Mr. T. W. Stanton: *Ostrea coalvillensis* Meek, *Ostrea sannionis* White, *Anomia* sp., *Pecten* sp., *Inoceramus erectus* Meek, *Gervillia* sp. cf. *G. propleura* Meek, *Cardium curtum* M. and H., *Cardium* sp., *Anatina*? sp., *Turritella spironema* Meek?, *Baculites compressus* Say.

Mr. Stanton states that they belong to a faunule that occurs in the upper part of the section at Coalville, Utah, and is also found in western Wyoming, occupying the stratigraphic position of the Niobrara, or not far above it. At no great distance above the sandstone occur distinctive Pierre fossils. A characteristic outcrop of the sandstone is shown in Pl. VIII.

PIERRE SHALE.

The thick deposit of dark shales constituting the Pierre formation outcrops in irregular areas on the flanks of the Owl Creek uplift. An exposure of moderate width extends along the south side of the uplift on branches of Muddy Creek, an extensive area occurs in the syncline in Owl Creek Valley near Middleton, another occurs in the syncline traversed by Dry Creek, and a northward-dipping succession of Pierre beds outcrops on the north side of the Thermopolis anticline. To the northwest and southeast of the mountains the formation is covered by Tertiary deposits.

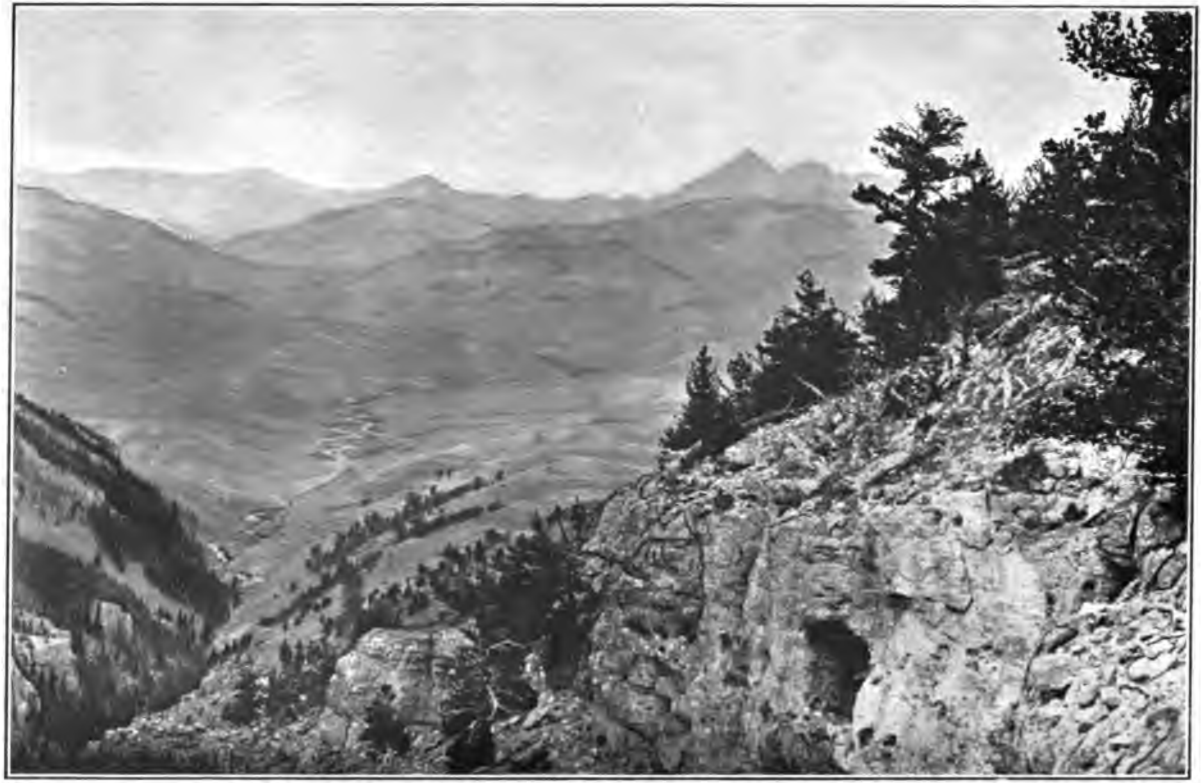
The thickness of the Pierre shale is approximately 1,000 feet in the Owl Creek region and to the northeast, but it is considerably more on the south side of the uplift. In the section of nearly vertical beds measured on the east side of the syncline of Dry Creek the thickness is 2,600 feet, and on Muddy Creek, southeast of Hollands, 2,250 feet are exposed between the top sandstone of the Colorado formation and the sandstone supposed to represent the Fox Hills formation. All the rocks are dark-gray shales, but occasional thin sandy beds occur at some localities. Oval concretions often occur and they generally contain distinctive Pierre fossils in moderate variety.

FOX HILLS AND LARAMIE FORMATIONS (?).

The Pierre shale on both sides of the Owl Creek uplift is succeeded by sandstones which are supposed to represent the Fox Hills sandstone, though no fossils have been found to establish a correlation. Next above are alternations of sandstones and carbonaceous and sandy shales, containing deposits of lignite, which ordinarily are supposed to represent the Laramie formation. These formations occupy synclinal areas of considerable extent in the valleys of Muddy, Dry, and Cottonwood creeks, and they underlie the Bighorn basin farther north. An outlier of moderate size occurs northwest of Middleton on the divide between Owl and Cottonwood creeks. In the steeply dipping beds on the north side of Muddy Creek Valley, a short distance west of the mouth of Sheep Creek, it was found that the interval from the Pierre shale to the base of the Tertiary conglomerates was 2,500 feet, of which the lower 225 feet are a massive buff sandstone supposed to represent the Fox Hills. The lower portion of the supposed Laramie formation contains deposits of lignite coal, but, owing to the scarcity of clear outcrops, it is difficult to trace the beds without making excavations. In the valleys of Dry and Muddy creeks there appears to be at least one bed that varies from 3 to 4 feet in thickness and may possibly be thicker at some points. At the coal mines north of Thermopolis the coal locally thickens to 14 feet and there are several thinner beds in the adjoining strata. North of Middleton the thickness of the lignite is about 4 feet and northeast of Embar it is reported that there are two beds, the lower one 2½ feet thick and the upper one less than 2 feet, separated by 4 feet of sandy shales. The formation presents prominent topographic features, usually rising in high buttes elevated from 200 to 300 feet above the adjoining valley of Pierre shale.

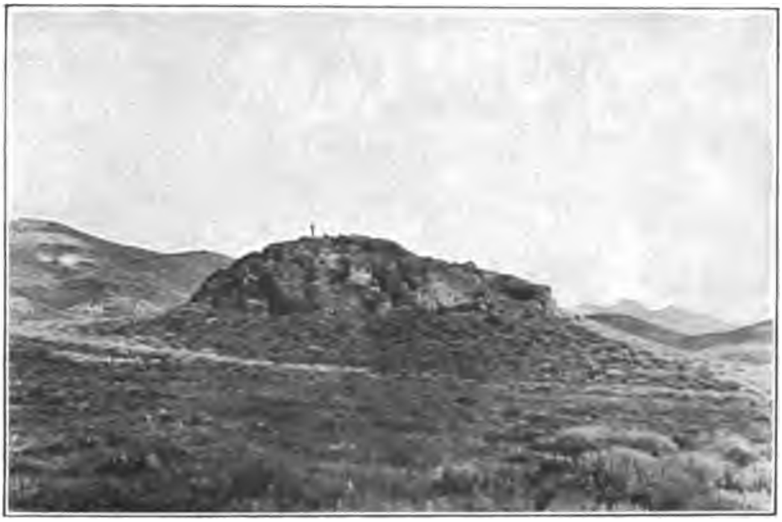
TERTIARY SYSTEM.

No special study has been given to the Tertiary deposits in the regions adjoining the Owl Creek uplift. They occupy a wide area in the Wind River basin to the south and constitute the Shoshone Mountains to the northwest. The beds in the Wind River basin, which have been called the Wind River formation, and are supposed to be of "Bridger" age, appear to be entirely distinct from the rocks of the Shoshone Mountains.



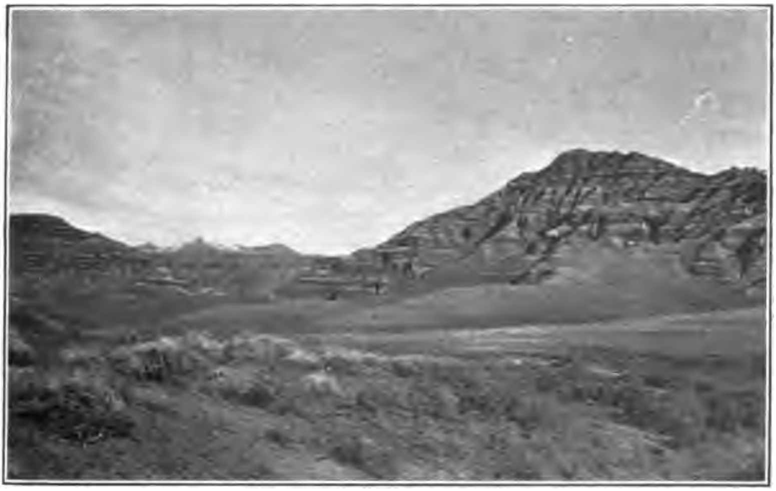
WASHAKIE NEEDLES AND SOUTH FORK OF OWL CREEK FROM THE SOUTHEAST.

Northward-dipping monocline of Madison limestone in the foreground. Volcanic and sedimentary rocks of Tertiary age in the middle-ground and distance.



A. VOLCANIC AGGLOMERATE ON MIDDLE FORK OF OWL CREEK, 7 MILES NORTHWEST OF ANCHOR POST-OFFICE, WYO.

In slopes to left are leaf-bearing sandstones of Fort Union age.



B. "BRIDGER" FORMATION IN WIND RIVER BASIN.

Photograph by W. H. Jackson.

SHOSHONE MOUNTAINS.

The Shoshone Mountains consist largely of volcanic agglomerates and lava flows, interbedded with sandstones and shales in a series having a thickness of several thousand feet. They overlap unconformably all the rocks of the Owl Creek range and rise far above its highest summits. (See Pl. IX.) A typical mass of agglomerate inclosed in sedimentary beds near the head of Middle Fork of Owl Creek is shown in Pl. X, *A*. At this locality a large deposit of fossil leaves was discovered in a shale in the series. According to Mr. Knowlton, these comprise the following species:

Equisetum sp. One fragment.
Lygodium kaulfusii Heer (L. neuropteroides Lesq.). Abundant.
Populus cuneata Newberry. Abundant.
Populus glandulifera Heer. Abundant.
Populus zaddachi Heer. Abundant.
Quercus olafseni Heer. Two examples.
Platanus sp.? Several fragments of large leaves.
Aralia whitneyi Lesq. Several fragments.
Aralia notata Lesq. Several fragments.
Aralia cf. A. radiata Ward. Two examples.
Sapindus obtusifolius Lesq. Two or three examples.
Cinchonidium cf. C. ovale Lesq. Two or three examples.
Carpites sp.

From a slightly higher horizon the following forms were obtained:

Fragments of the rays of a large palm.
Ficus sp. ?
Acer cf. A. bolanderi Lesq. One small leaf.

WIND RIVER BASIN.

The Tertiary rocks of the Wind River basin consist of sandstones, clays, and sandy clays, which in the greater part of the area lie nearly horizontal. To some extent they are cut into bad lands, as shown in Pls. X, *B*, and XVIII. They extend to the foot of the Owl Creek Mountains and apparently at one time reached far up the slopes, for several outlying remnants still remain at an altitude of about 8,000 feet in the vicinity of longitude 109°. They are supposed to be underlain by the "Wasatch" formation in at least part of the Wind River basin, and this formation may appear in some of the local uplifts which have steeply upturned the Tertiary beds in the vicinity of Muddy Creek. In these upturns a series of conglomeratic beds is exposed in conformable succession with the supposed Laramie formation, all having a nearly vertical dip.

QUATERNARY SYSTEM.

The principal Quaternary deposit in the Owl Creek region is the alluvium which borders the larger streams. Some remnants of higher terrace gravels also occur. There are hot-spring deposits in the vicinity of Thermopolis, and apparently some morainal material occurs on the divide between Red and Dry creeks, 5 miles northeast of Black Mountain.

The broadest areas of alluvium are along Bighorn River above the canyon and below the Thermopolis uplift, along Wind River, and on Owl Creek from Embar eastward. Most of the streams in the higher lands are eroding and leave but little deposit on their freshet plains. The supposed morainal deposit above referred to is on the limestone ridge near the head of Red Creek, at an altitude of 9,000 feet. In an area of several acres there is a large accumulation of bowlders of granite and volcanic rocks, presenting an irregular surface somewhat suggestive of a moraine. Possibly it is the product of an old glacier from Crow Creek Valley in the Shoshone

Mountains to the north. There may be other similar deposits in the higher slopes of this range, but no search for them was made. A thick cap of very large granite bowlders, suggestive of glacial origin, occurs on the top of a high isolated knob on the east side of Dry Creek, precisely 5 miles due N. 60° E. of Black Mountain. The hot-spring deposits are described on pages 39–40, in connection with the hot springs about Thermopolis, by which they were laid down.

STRUCTURAL GEOLOGY.

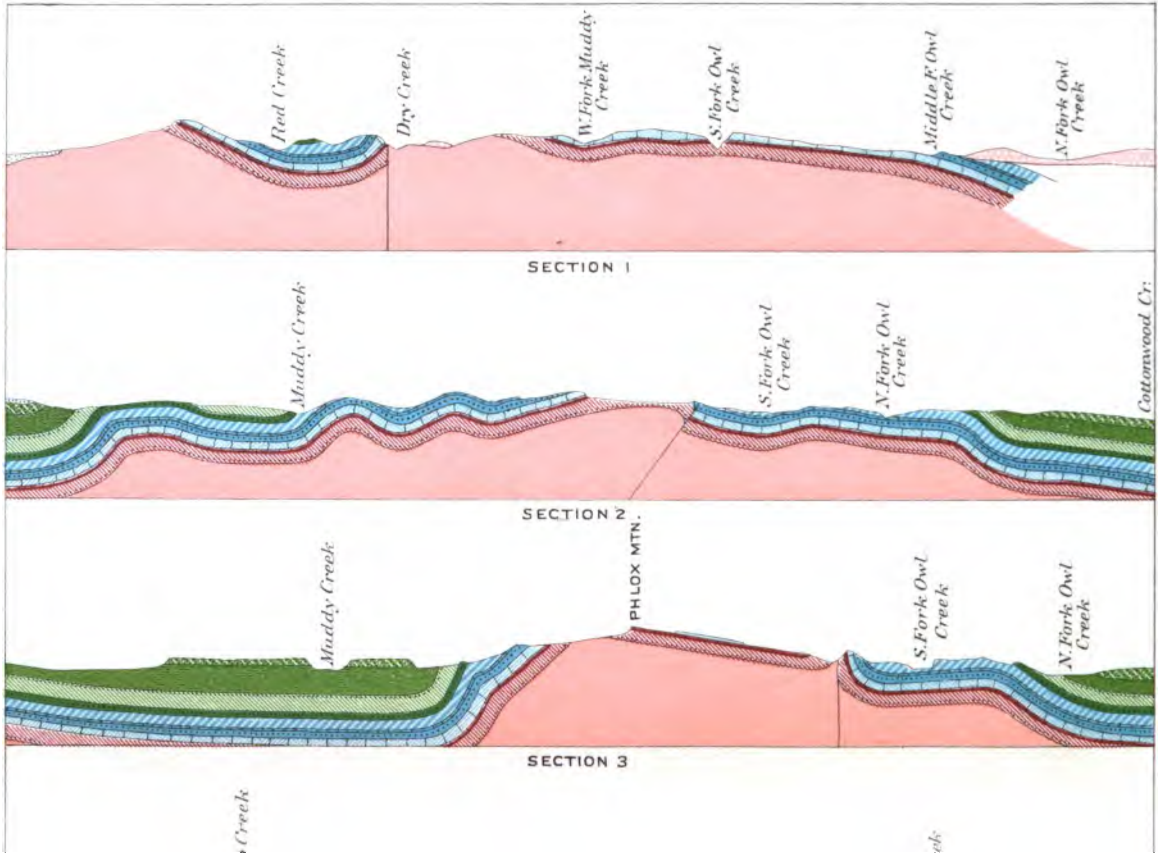
GENERAL STRUCTURE OF THE OWL CREEK UPLIFT.

The Owl Creek Mountains are due to an anticline, or arch of the crust of the earth, which in the highest portion of the uplift has risen about 10,000 feet. It is a westward prolongation of the Bighorn Mountain uplift, with increased elevation, and is separated from the latter by a low saddle in the vicinity of Bridger Creek. Bighorn River crosses the Owl Creek uplift near its east end, and the portion east of this canyon is known as the Bridger Range. To the west it passes beneath the great series of Tertiary volcanic and associated sedimentary rocks of the Shoshone Mountains. It lifts a thick series of Paleozoic and Mesozoic formations high above the plains, and, owing to the deep erosion of its crest, presents a central nucleus of pre-Cambrian granites and crystalline schists, from which the rocks dip at varying angles on either side, to the north into the Bighorn basin and to the south into the Wind River basin. The most elevated portion of the uplift is south of Embar, where the granite summits rise to an altitude somewhat more than 9,000 feet, or about 4,000 feet above that of the adjoining basins.

In Pls. XI and XII is shown the configuration of the principal structural features of the uplift. The main anticline is somewhat complex in form and there are numerous branching flexures and a number of faults of great throw. In general, the south side presents dips steeper than those on the north. The structure of the lower portion of the south side of the uplift is widely obscured by the overlap of the Bridger formation, except in the vicinity of longitude 109°, where several local flexures are exposed, extending some distance south from the foot of the mountains. A notable feature in the main uplift is its greatly diminished altitude southwest of Thermopolis, where it is crossed by the road to Lander. West of this depression, which is not only structural but topographic, rises the most elevated portion of the uplift, marked by a long belt of high granite ridges. Black Mountain, at the west end of the range, is due to local doming, or increase of uplift. The long western slope of the main anticline, where it is crossed by the canyon of Bighorn River, is a notable feature. To the west this long monocline develops into an anticline and syncline, the former pitching down very steeply at the big bend in Red Creek. The anticline at Thermopolis is due to a sharp upturn on the general northern slope of the uplift. The faults are of various lengths and except the series of block faults in the vicinity of Bighorn Canyon develop in the steeper portions of the upturned strata. One of the most prominent faults extends along the northwest side of the range, crossing South Fork of Owl Creek near longitude 109° and developing into a steep upturn south of Embar. A branch of this displacement crosses the range east of Phlox Mountain and extends along its southern side for some distance to longitude 108° 30′, where it passes beneath "Bridger" beds. Half a mile west of this point it has a vertical displacement of 7,000 feet, bringing granite into contact with the upper portion of the Pierre shale.

REGION ABOUT THERMOPOLIS.

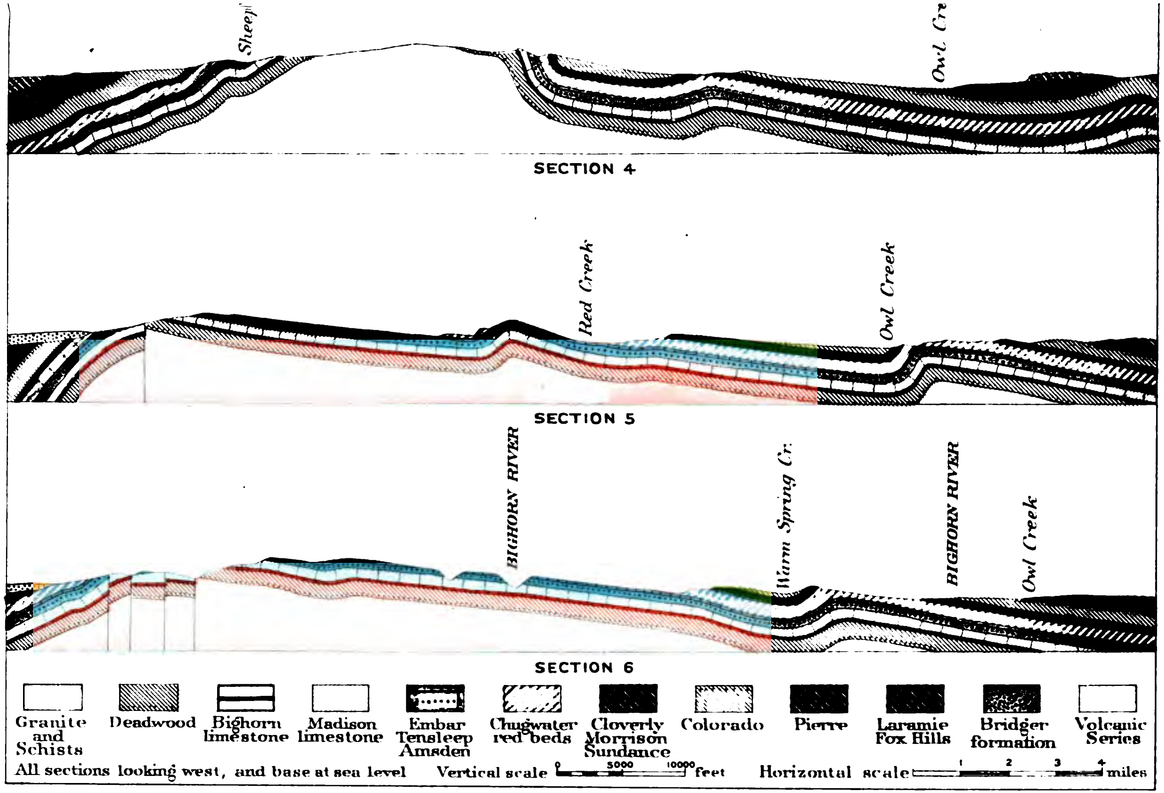
The principal structural features in the vicinity of Thermopolis are shown in section 6 of Pl. XI. To the south there is a gentle monoclinal slope from the summit of the Owl Creek Mountains into a syncline, the axis of which crosses Bighorn River half a mile south of Thermopolis. On the higher mountain slopes this monocline



SECTION 1

SECTION 2

SECTION 3



SECTIONS ACROSS OWL CREEK MOUNTAINS ALONG LINES SHOWN ON PLATE 1

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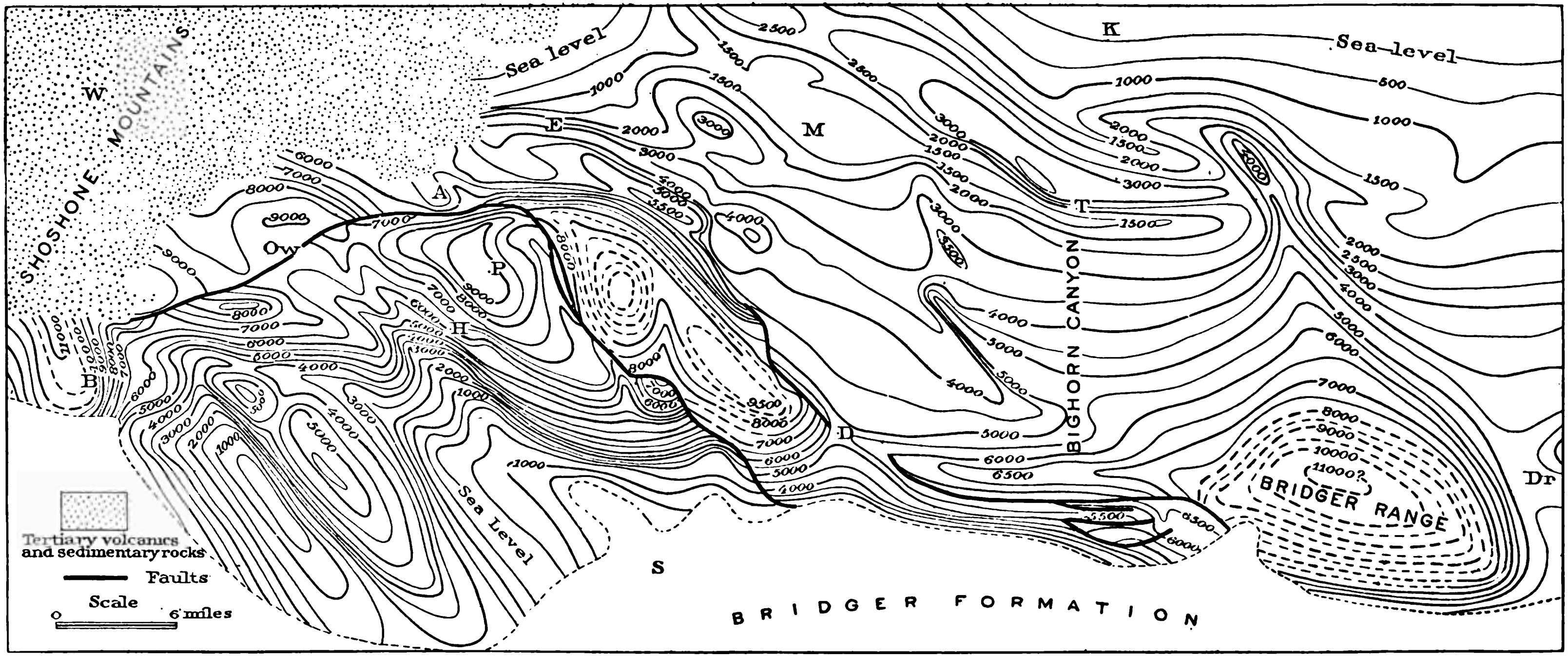


DIAGRAM SHOWING CONFIGURATION OF OWL CREEK AND BRIDGER UPLIFT.

T, Thermopolis; Dr, Deranch; E, Embar; A, Anchor; H, Holland's ranch; M, Middleton; P, Phlox Mountain; B, Black Mountain; D, gap on Lander-Thermopolis road; S, mouth of Sheep Creek; Ow, Owl Creek Canyon; K, mouth of Kirby Creek.

presents a wide area of Embar limestone, at the foot of which are the overlying Chugwater red beds. The latter extend to the west up the valley of Red Creek and to the east up the valley of Buffalo Creek. To the west this Embar slope bifurcates, owing to a syncline in which the red beds extend from Red Creek Valley far to the southeast. On the north side of this syncline the limestone rises in an anticline, with steep dips on its southwest side and long slopes on the north side. At the big bend in Red Creek it pitches down rapidly, as shown in Pl. XIII, *B*. Overlying the red beds north of Red and Buffalo creeks there is a regular succession of Sundance, Morrison, and Cloverly formations, the latter capping and constituting the northern flank of a ridge of considerable prominence a short distance southwest and southeast of Thermopolis. The center of the syncline is at the foot of this ridge and in it the Cloverly sandstone passes under about 500 feet of Colorado (Benton) shales.

Next north is the Thermopolis anticline, a flexure of moderate height, with steep dips on its southern side and gentle dips on its northern side, exhibiting about half the thickness of the Chugwater red beds where it is crossed by Bighorn River. (See Pl. XIII, *A*.) One of the most salient features of this uplift is the hogback of Cloverly sandstone which passes through the northern portion of Thermopolis, but is eroded to some extent near the river. It presents dips of from 50° to 70°. A characteristic exposure is shown in Pl. VII, *A*. A short distance northwest of Thermopolis, where the dips are steepest, the Embar limestone appears in the axis of the uplift, giving rise to a rounded ridge of considerable prominence, flanked on either side by slopes of Chugwater red beds.

On the northern slope of the Thermopolis uplift there is a regular succession from the Chugwater red beds to the Laramie formation, the latter appearing a short distance north of the mouth of Kirby Creek. This monocline is interrupted 4 miles northeast of Thermopolis by a small anticline, which brings the Cloverly sandstone to the surface along Bighorn River and in the ridge east. The Thermopolis uplift is traceable for 15 miles or more northwest of Thermopolis. Where it is crossed by Owl Creek it exhibits the entire thickness of the Chugwater red beds, and in the crest of the arch a small area of the top bed of the Embar limestone appears. Four miles northwest the flexure pitches down rapidly and red beds, Sundance, Morrison, and Cloverly formations pass rapidly beneath the surface. The syncline, which lies between this uplift and the main mountain slope, also deepens in approaching Owl Creek, so that it holds at Middleton a thick mass of Pierre shale, and near the line of section 4, Pl. XI, an outlier of supposed Fox Hills-Laramie sandstones and coal measures. In this region the dips are very low to the south, to and up the slope of the main Owl Creek Mountain Range, so that there are long slopes of Cloverly sandstone culminating in a high ridge which overlooks a wide valley of Chugwater red beds about the headwaters of Red Creek.

NORTHERN CENTRAL SLOPES.

The northern slopes of the Owl Creek uplift, from the head of Mud Creek to the vicinity of Anchor, present considerable variation in structure. There is in general a monocline sharply upturned along the higher mountain slopes, but with gentle dips near Owl Creek. A subordinate anticline occurs in the middle slopes, which gives rise to a prominent rounded ridge of Embar limestone southeast of Embar, a wide area of Chugwater red beds south and southwest of Embar, and a number of areas of Chugwater red shales along the various branches of Mud Creek. Near the line of section 4, Pl. XI, the syncline between the subordinate anticline and the main mountain crest holds an area of Colorado (Benton) shale. Another subordinate anticline, considerably smaller than the one above described, traverses the Colorado shale area halfway between Middleton and Embar. Along the valley of Owl Creek near the junction of North and South forks a small area of Cloverly sandstone and the underlying Morrison formation is exposed in the axis of this arch.

North of Owl Creek Valley there is a shallow syncline, in the center of which occur supposed representatives of the Fox Hills and Laramie formations, constituting a portion of the divide between Owl and Cottonwood creeks. The outlier of Laramie coal measures northwest of Middleton lies in this syncline.

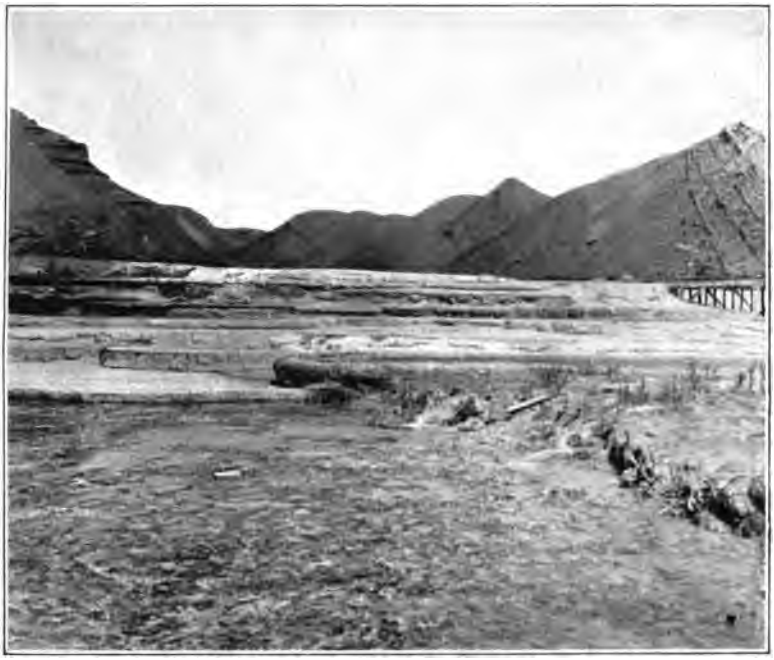
CENTRAL ANTICLINE EAST OF PHLOX MOUNTAIN.

The main axis of the Owl Creek uplift follows approximately the summit of the mountain. East of longitude 108° 30′ this summit consists of sedimentary rocks, but on that meridian and farther west the underlying granites rise rapidly in a series of prominent ridges. Near Bighorn Canyon the mountain presents a long, gentle slope to the north, covered mostly by Embar limestone, and there are steep slopes, with correspondingly steep dips, to the south. Along the southern face, near the top of the mountain, appear the Tensleep, Amsden, Madison, Bighorn, and Deadwood formations, and in and near Bighorn Canyon the underlying granites and schists are seen. The steep eastern limb of the arch is broken by several faults, which reach their maximum development and number at or near the canyon. The relations of these faults are shown at the left-hand end of section 6, Pl. XI. The principal displacement amounts to over a thousand feet, with the drop on the south side, and it extends westward along the mountain front for 10 miles or more, finally dying out as the main flexure pitches down in the vicinity of the gap where the mountain is crossed by the Lander road. In this gap the anticline presents an arch of Tensleep sandstone, with gentle dips on the north side and slightly steeper ones on the south. To the west of the gap there is a steep upward pitch in the uplift by which the granites are brought to the surface in an area about 3 miles wide.

With increased uplift faults develop on either side of the arch. One on the south side having a displacement of 7,000 feet brings the upper beds of the Pierre into contact with the granite. The fault on the north side of the mountain varies greatly in throw, but near the head of Red Creek it brings the middle Deadwood and Cloverly formations into contact, a displacement of 3,100 feet. Both faults diminish to the west. The one on the north side merges into a steep upturn, as shown in section 4, Pl. XI, and the one on the south side, with varying throw, extends entirely across the range and thence along its north side. East of Phlox Mountain this fault presents considerable complexity, and at one point bifurcates in such a manner that a wedge of granite appears in the midst of an area of Madison limestone. In this vicinity a deep syncline, holding the Madison limestone and Amsden formation, extends across the main axis of the mountain, and there is another small syncline, holding the Deadwood formation and Bighorn limestone, higher on the mountain slopes near section 4, Pl. XI. Along the south slope of the mountain in this vicinity there are several branch anticlines which extend diagonally to the southeast out of the main uplift and pitch rapidly downward. One of the most prominent of these constitutes the ridge west of Sheep Creek, which is composed mainly of Tensleep and associated strata, separated from the higher mountain slopes by a valley of Chugwater red beds. On the north side of this valley passes the fault above referred to, which, in this vicinity, brings the red beds into contact with the granite.

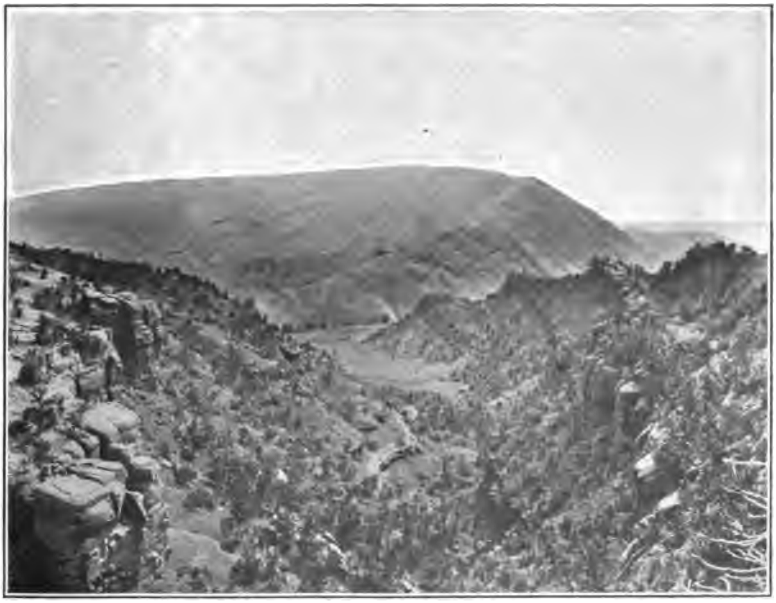
REGION WEST OF PHLOX MOUNTAIN.

Phlox Mountain is due to a cap of Bighorn limestone on a local dome on the crest of the main Owl Creek uplift. On the west slope of this dome the granite and associated rocks have been bared by erosion for some distance, but farther down its slope the overlying sedimentary rocks cross the mountains in regular succession. At the west end of the dome are two synclines marked by valleys containing Chugwater red beds and separated by an anticlinal ridge, mostly of Embar limestone. These flexures pitch down to the south and, in the vicinity



A. UPLIFT OF CHUGWATER RED BEDS AND OVERLYING FORMATIONS AT THERMOPOLIS, WYO.

Looking eastward across hot spring deposits to high point of Cloverly sandstones in distance.



B. WESTERN TERMINATION OF BRANCH ANTICLINE SOUTHWEST OF THERMOPOLIS, WYO.

Looking south. Shows long dip slope of Embar limestone descending to Red Creek. Chugwater Red Beds in foreground.

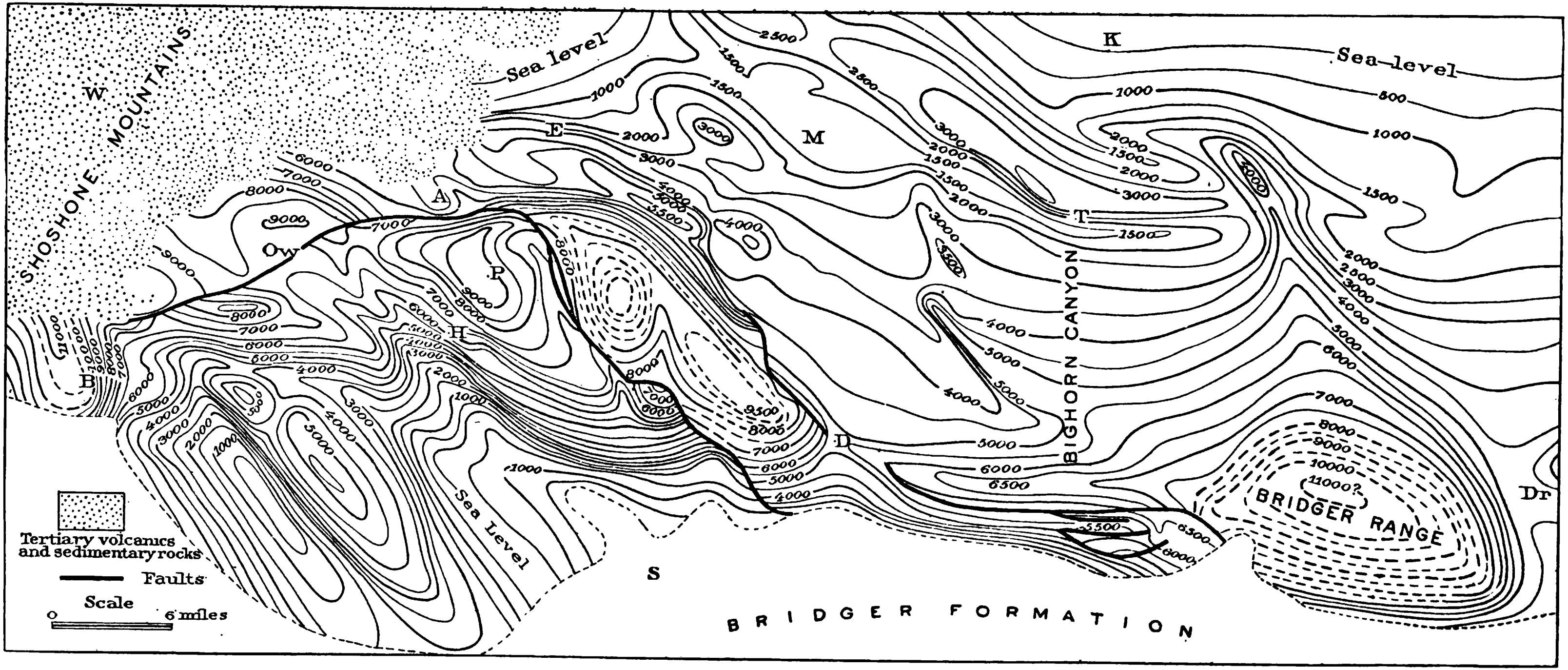


DIAGRAM SHOWING CONFIGURATION OF OWL CREEK AND BRIDGER UPLIFT.

T, Thermopolis; Dr, Deranch; E, Embar; A, Anchor; H, Holland's ranch; M, Middleton; P, Phlox Mountain; B, Black Mountain; D, gap on Lander-Thermopolis road; S, mouth of Sheep Creek; Ow, Owl Creek Canyon; K, mouth of Kirby Creek.

materials of which they are composed were originally gravel, sand, or mud derived from the waste of older rocks or chemical precipitates from salty waters.

These rocks afford a record of physical geography from Middle Cambrian time to the present. There has been considerable diversity of conditions, but an extensive stratigraphic record is presented. Some of the chapters of the history are clear, but in others much additional study will be required before we can know the complete sequence of events. The composition, appearance, and relations of strata show in some measure the conditions under which they were deposited. Sandstone, ripple-marked by waters and cross-bedded by currents, and shales cracked by drying on mud flats, were deposited in shallow water; pure limestones generally indicate open seas and scarcity of land-derived sediment. The fossils that the strata contain may belong to species known to inhabit waters which are fresh, brackish, or salt, warm or cold, muddy or clear.

The character of the adjacent land may be shown by the nature of the sediments derived from its waste. The quartz, sand, and pebbles of coarse sandstones and conglomerates, such as are found in the Deadwood, Cloverly, and Laramie formations, had their original source in crystalline rocks, but have been repeatedly redistributed by streams and concentrated by wave action on beaches. Red shales and sandstones, such as make up the "Red Beds," usually result directly from the revival of erosion on a land surface long exposed to rock decay and oxidation, and hence covered by a deep residual soil. Limestones, on the other hand, if deposited near the shore, indicate that the land was low and that its streams were too sluggish to carry off coarse sediments, the sea receiving only fine sediment and substances in solution.

The older formations exposed by the Owl Creek uplift were laid down from seas which covered a large portion of the central-western United States, for many of the rocks are continuous over a vast area. The land surfaces were probably large islands of an archipelago, which was to some degree coextensive with the present Rocky Mountain province, but the peripheral shores are not even approximately determined for any one epoch, and the relations of land and sea varied greatly from time to time. Pursuing these general ideas more in detail, one finds that the strata brought to view by the Owl Creek uplift record many local variations in the ancient geography and topography of the continent.

CAMBRIAN SUBMERGENCE.

One of the great events of early North American geologic history was the wide expansion of an interior sea over the western-central region. The submergence reached the Rocky Mountain province in Middle Cambrian time and for a while found an irregular shore line about a great series of archipelagoes. From the ancient crystalline rocks of these shores waves and streams gathered and concentrated sands and pebbles, which were deposited as a widespread sheet of sandstone and conglomerate on sea beaches, partly in shallow waters offshore and partly in estuaries. Numerous exposures are now found in which these sediments, containing much local material, may be seen abutting against the surface of the crystalline rocks, which formed these shores. The central portions of the Bighorn Mountains and the Black Hills were, probably, islands in the earlier stage of this period, and the Laramie Range and Rocky Mountain Front Range were highlands rising out of the Cambrian Sea. After these earliest shore-line conditions the altitude was reduced by erosion, and the area was, possibly, lessened by submergence. Some of the islands yielded the finer-grained muds now represented by the shales and limestones which occur in the upper portion of the Cambrian, but in many regions the land surface of crystalline rocks was buried beneath the sediments. The limestone conglomerates of the Deadwood formation indicate recurrence of shallow-water conditions, probably marking the beginning of emergence. which lasted through the later part of Cambrian time.

ORDOVICIAN SEA.

Early in Ordovician time there was wide submergence in portions of the northern Wyoming region, accompanied by extensive deposition of lime carbonate, at first mixed with a large amount of silica. Some of the shores of this sea may have been the southern part of the Bighorn Mountains and the Black Hills, with land areas in central Wyoming and farther south; but the limits of the submergence in other directions are not known. In the region of the Owl Creek Mountains a moderate thickness of sediments was deposited, continuing into the middle of the Ordovician, when there was uplift for a considerable time, followed near the end of the period by submergence in some areas, in which limestones representing the Richmond series were deposited.

SILURIAN-DEVONIAN CONDITIONS.

From the close of Ordovician to early Carboniferous time the Owl Creek Mountains present no geologic record, the Silurian and Devonian being absent. This is probably because there was an extensive but very shallow sea, or land so low as to leave no noticeable evidence of erosion. Whether it remained land or sea, or alternated from one to the other condition, the region shows no evidence of having undergone any considerable uplift or depression until early in Carboniferous time, when there was a decided subsidence that established relatively deep water and marine conditions, not only over this area, but generally throughout the northern Rocky Mountain province.

CARBONIFEROUS SEA.

Under the marine conditions of the early Carboniferous carbonate of lime was laid down, which is now represented by a very thick formation, known as the Madison limestone. As no coarse deposits occur, it is possible that no crystalline rocks were exposed above water in this region, though in other regions to the south the limestone, or its stratigraphic equivalents, was deposited immediately upon such rocks. Later in Carboniferous time the conditions changed and a sheet of red shale of wide extent was deposited, followed by alternations of pure limestones and sandy limestones and local sand deposits several hundred feet thick, constituting the Amsden formation. This deposition was followed by an uplift, during which shallow waters and strong currents deposited an extensive body of sands, known as the Tensleep sandstone. In the Owl Creek and southern Bighorn areas this condition gave place to the deposition of clay and carbonate of lime, now represented by the Embar formation. Then followed a period of general uplift culminating in Permian time in a widespread sea or lake of saline water in which the Chugwater formation accumulated. This great mass of red shales, with its extensive interbedded deposits of gypsum, presumably products of an arid climate, accumulated to a thickness of over a thousand feet in some parts of the area. There is such uniformity of the deep-red tint that this is undoubtedly the original color. It is constant not only over practically the entire outcrop of the formation, but also throughout its thickness, as is shown by deep borings. It is, therefore, not due to later or surface oxidation. This deposition of red mud was interrupted from time to time by chemical precipitation of comparatively pure gypsum, in beds ranging in thickness from a few inches to 40 feet and usually free from mechanical sediments.

It is apparent that these beds are the products of evaporation while mechanical sedimentation was temporarily suspended, a condition indicative of greatly diminished rainfall; otherwise it is difficult to account for their nearly general purity. Most of the red deposits were laid down in shallow water, so that there must have been a subsidence which as a rule kept pace with deposition. At an early stage in the deposition of the red beds there was a widespread interruption in the shale sedimentation and a thin but wonderfully persistent bed of limestone was laid down. It is only a few feet thick in the Bighorn-Owl Creek region, but in the Black Hills and some other localities it is 50 feet thick and is known as the Minnekahta limestone. It contains Permian fossils, and as fossils of this age also occur in local limestone deposits nearly to the top of the red beds, they are nearly all, if not all, of that age. Possibly the deposition extended into the Triassic and even into the earlier Jurassic, but there is no definite evidence of this. In most localities there is evidence of uplift and erosion of the Chugwater red beds in an interval prior to the deposition of the marine Jurassic beds of the Sundance formation.

JURASSIC SEA.

In Wyoming the Jurassic was a period of varying conditions, shallow and deep marine waters alternating. The materials are nearly all fine grained and indicate waters without strong currents. Some of the earliest deposits are fine-grained sandstones or sandy shales, in part ripple-marked, evidently laid down in shallow water and probably the product of a time when sedimentation was in excess of submergence, if not during an arrest of submergence. An extensive marine fauna and limestone layers in the upper shales of the Sundance formation indicate that deeper or quieter water followed, but more sandy sediments appear near the top, indicating the resumption of shallow-water conditions.

CRETACEOUS SEA.

During the Cretaceous period deposits of various kinds, but generally uniform over wide areas, gathered in a great series, beginning with such as are characteristic of shallow seas and estuaries along a coastal plain, passing into sediments from deep marine waters, and changing toward the end to fresh-water sands and clays with marsh vegetation. The earliest deposits constitute the Morrison formation, a widespread sheet of fine-grained materials, mixtures of clay and fine sand, with thin, irregular bodies of coarser sand deposited by streams or along shores, and with occasional thin beds of limy sediments. Huge saurians were abundant, as shown by the frequent occurrence of their remains in the deposits, though it is possible that this abundance is due mainly to increased mortality or more favorable conditions of preservation, or both.

Morrison time was succeeded abruptly by a change to conditions under which the coarse-grained, cross-bedded, massive basal conglomerates and sandstones of the Cloverly formation were deposited. Although the deposits change abruptly and there is occasional local channeling of the surface of the soft Morrison deposits, the erosion appears to be of remarkably small amount and no more than would be expected to result from strong currents bearing coarse sands and pebbles. It is believed that there was no great interval of uplift and erosion following the Morrison deposition, for if there had been the soft deposits would have been widely removed. It is a significant fact, indicating regular succession, that some of the saurians of Morrison time continued into the next epoch. The coarse deposits of the lower part of the Cloverly were derived from sources not fully located and spread by strong currents over a wide area. In the earlier stages there were some coaly deposits, but apparently no such coal beds as are found in the Black Hills region. The coarser beds are usually less than 50 feet thick and give place to massive clays and sandy clays, mostly of purplish color, not unlike the Morrison clay, which usually have a thickness less than 100 feet and are supposed to represent the Fuson formation of the Black Hills.

The "Dakota" sandstone appears also to be recognizable at most localities. There is no evidence of unconformity at the top of the Cloverly formation, but at the beginning of the Benton there was everywhere in the region a rapid change of sediments to dark-colored, thin-bedded clays. These are the products of a later Cretaceous submergence in which marine conditions prevailed and it continued until several thousand feet of clays were deposited during the Benton, the Niobrara, and the Pierre epochs. In Benton time there were occasional thin deposits of sand, especially at first and in the middle, when some very fine grained sandy clays were laid down, now known as the Mowry beds. The calcareous sediments of the Greenhorn limestone in the middle of the Benton are not represented in the Owl Creek-Bighorn region and the Niobrara sediments were clays and perhaps sandstones also, lacking the chalky ingredient which characterizes them in other regions to the south. The period of Pierre deposition was long, for over 2,500 feet of dark clays, deposited slowly under very uniform conditions, accumulated in some portions of the region. The retreat of the Cretaceous sea, which is usually believed to correspond with the Fox Hills epoch, resulted in extensive bodies of brackish water which spread sand over the clay beds, and then fresh waters which deposited the sands, clays, and marsh materials of the Laramie. Laramie deposition progressed until several thousand feet of shales and sands accumulated, including scattered beds of carbonaceous materials which are now lignite coal, in some cases 20 feet or more in thickness. It is believed that this epoch may have extended into early Eocene time.

EARLY TERTIARY MOUNTAIN GROWTH.

Extensive uplift took place in the Rocky Mountain province in early Tertiary time. This fact is clearly indicated in most of the mountain regions, where various Eocene deposits lie on an eroded surface having the general outlines of the present configuration, a relation which indicates that the uplifts were truncated and the larger outlines of their topography established in early Eocene time. A part at least of the great mass of eroded material was deposited in the basins adjoining the uplifts and constitutes the "Bridger," "Wasatch," and other formations.

LATER TERTIARY PRODUCTS.

Oligocene and later Tertiary deposits were laid down by streams and local lakes and finally covered much of the Northwest to a level now high on the flanks of the various mountain ranges. In part of the region erosion has removed them from most of the higher land, especially along the steeper slopes. Some deposits of supposed Tertiary age remain in the center of the Bighorn Mountains at altitudes of from 8,000 to 9,000 feet, and along the Front Range at altitudes of from 6,000 to 7,000 feet, probably the remnants of much more extensive sheets. In the northwestern portion of Wyoming there are vast accumulations of volcanic and associated sedimentary rocks of Tertiary age, constituting the Shoshone and other ranges. They are the products of an epoch of great volcanic activity which probably continued through a long time.

QUATERNARY CONDITIONS.

Several small glaciers remaining in the higher portions of the Bighorn and Wind River mountains are diminutive remnants of much more extensive bodies of ice which formerly occupied the principal valleys of the highlands. In this respect the history of the northwestern Wyoming region is similar to the history of other high ranges similarly situated in the western part of the United States. The glacial history is complex, and the great glaciers, which have left the most distinct records of themselves, were the successors of earlier ones, the marks of which have been partly effaced by weathering and erosion. On the lower mountains, such as the Owl Creek and Bridger ranges, and through the lower slopes of all the mountains, the principal feature of Quaternary time has been erosion, which has developed the minor features of the present topography. Some of the larger streams have not only cut deep, wide valleys, but covered their bottoms with wide terraces of alluvium, and the deposition of this material continues during the freshets.

MINERAL RESOURCES.

GENERAL STATEMENT.

There has been no development of mineral resources in the Owl Creek Mountains and adjacent territory, but when the granites and associated rocks of the region are thoroughly explored, gold, copper, and other metals may be discovered and the Laramie formation will be found to contain deposits of coal of local value. Petroleum and underground waters are also worthy of consideration. Large deposits of gypsum occur in the "Red Beds" on both sides of the uplift.

GOLD.

As promising gold prospects have been recently discovered in the Bridger Range, which constitutes the eastward continuation of the Owl Creek uplift, it is not improbable that similar conditions may be found in the Owl Creek Mountains. Portions of the granites and associated rocks are considerably mineralized, as shown by the presence of veins and impregnations of rusty quartz which are worthy of systematic inspection. There are no young igneous rocks in the main Owl Creek uplift, either in the granites or traversing the overlying sedimentary rocks. Gold has been found in some of the volcanic rocks of the Shoshone Mountains in the Kirwin region, and it is possible that similar conditions may exist in the great body of these rocks lying immediately west of the Owl Creek Mountains.

Probably it will be useless to look for gold in the sedimentary rocks of this region, but the granites and associated schists in the area shown on the accompanying geologic map (Pl. I) should be thoroughly prospected. In general the gold might be expected to be free so that it could be detected by crushing the rock and panning, but it may also occur in various combinations. At various points in the granite and associated schists, impregnations of iron pyrites and other sulphides were observed, which may prove to be gold bearing. Quartz containing free gold in clearly discernible flakes has been reported from the granite area of the Owl Creek Mountains, but the precise locality has not been divulged. Gold may possibly occur in small placer deposits along streams leading out of the granite areas of the uplift. In Crow Creek Valley there are numerous accumulations of sands which may prove to contain gold or other minerals, but nothing of value has yet been found in them.

COPPER.

Small amounts of copper ore were observed at various points in the granite in the higher central portion of the Owl Creek Mountains, but no promise of large deposits was found. The conditions appear to be similar to those in the Bridger and Bighorn uplifts to the east and north, where small amounts of copper minerals frequently occur in small veins in the granite. Thorough prospecting may, however, bring to light workable veins, but they should be looked for only in the areas shown on the geologic map as outcrops of granite and schists.

BLACK SAND.

More or less black sand is mixed with all the stream deposits derived from the granite areas, but apparently no large deposits occur. The minerals observed in this material are mostly magnetite and hornblende, but there is a possibility that platinum and various heavy minerals containing rare earths may also be included. It is important to save the heavier portions of black sands and have them tested for minerals of value, especially platinum.

COAL.

The formation which is supposed to represent the Laramie contains lignite coal beds on both sides of the Owl Creek uplift. The workable beds occur in the lower portion of the formation. A number of mines have been opened along the southern margin of the formation north of Thermopolis, Middleton, and Embar. The largest opening is known as the McDonald mine. Its entire product is used locally in Thermopolis and vicinity and is estimated at about 1,000 tons a year. The principal bed is 9 feet thick, overlain by a bed of sandy clay a few inches thick, above which is another coal bed 5 feet thick, making a total thickness of about 14 feet. Five other coal beds occur, four below and one above the 14-foot bed. Three of the lower beds are said to be workable. The uppermost of these, which lies 25 feet below the 14-foot bed, is 3 feet thick and apparently of good quality. The coal is bright, firm, and free burning. It gives a brown streak, breaks in blocks, and does not crumble on exposure. An analysis of the coal from the McDonald mine, made by F. J. Augier, is as follows: Moisture, 14.86; volatile matter, 37.54; fixed carbon, 43.94, and ash, 3.66 per cent, with a fuel ratio of 1.17. One of the beds of this series, about 5 feet thick, is worked for local use on the east side of Bighorn River, a mile north of the mouth of Kirby Creek. About 4 miles northeast of Embar the coal has been worked to some extent, but none has been obtained in recent years. Two beds are exposed, the lower one 2½ feet thick and the upper one less than 2 feet, separated by 4 feet of sandy shales. The dip is 5° NE. The coal is a bright, hard, oily looking lignite, containing much water, low ash, and exceptionally high fuel ratio. An analysis given by Eldridge shows the following: Moisture, 15; volatile matter, 46.69; fixed carbon, 34.27; ash, 4.04, and sulphur, 0.39 per cent, with a fuel ratio of 0.73.

Another small opening known as the Eades mine is on the north slope of the Laramie outlier, 3 miles northwest of Middleton post-office. The coal here is 4 feet thick and occurs in the massive gray sandstone of the basal Laramie. The dip is 9° N. The coal is black, with bright luster and uneven fracture, and does not weather easily.

Doubtless these coal beds are continuous throughout the formation in the outcrop areas shown on the maps (Pls. I and XVII). The coal south of the Owl Creek Mountains occurs mostly in Muddy Creek Valley, though possibly there is also some coal in the outcrop of the supposed Laramie formation on the east side of Dry Creek. Owing to the lack of clear exposures the thickness and extent of the coal beds in Muddy Creek Valley could not be ascertained. They occur in the lower portion of the formation, and one bed attains a thickness of 4 feet at several points. The coal is the usual lignite, admirably suited for local use, and doubtless it will be of much value to the settlers when the land in the northern portion of the reservation is taken up. Probably a considerable portion of the central part of the reservation is underlain by the Laramie formation, containing lignite beds, but owing to the thick covering of Tertiary deposits the coal may never be found, unless possibly by deep wells. The only mine found is a small pit south of Le Clair's ranch on West Fork of Sheep Creek.

GYPSUM.

The Chugwater formation contains extensive deposits of gypsum, especially along the southern side of the Owl Creek uplift from Sheep Creek westward. This is the mineral from which plaster of Paris is prepared by calcining, to drive off the chemically combined water, and pulverization. In the vicinity of Hollands and to the west, as well as in Red Creek Valley, southwest of Thermopolis, the principal bed of gypsum lies near the top of the formation and attains a thickness of from 30 to 40 feet over the entire area. Plaster of Paris is sold at such a low price that it can not be produced profitably in regions where the cost of transportation to market is high.

BENTONITE.

The Colorado shales contain widespread deposits of bentonite, a clay having remarkable absorptive properties. The material is especially conspicuous in the vicinity of the several forks of Muddy and Dry creeks, where the beds attain a thickness of from 2 to 3 feet and more, and are very noticeable by the white color of their outcrops, in striking contrast to the dark gray of the inclosing shale. Bentonite has been utilized to some extent as a paper filling, as packing for horses' hoofs, in the manufacture of dynamite, and for various other purposes in which a highly absorbent medium is desired.

FULLER'S EARTH.

The material known as fuller's earth is a porous clay of gray or pinkish color and massive, crumbly appearance when dry. It is extensively used for filtering oils and other materials to lighten their color. Deposits of clays having this general character were observed in the "Bridger" formation at various points, but no tests were made of their capabilities, so that no prediction can be made as to the value of the material.

PETROLEUM.

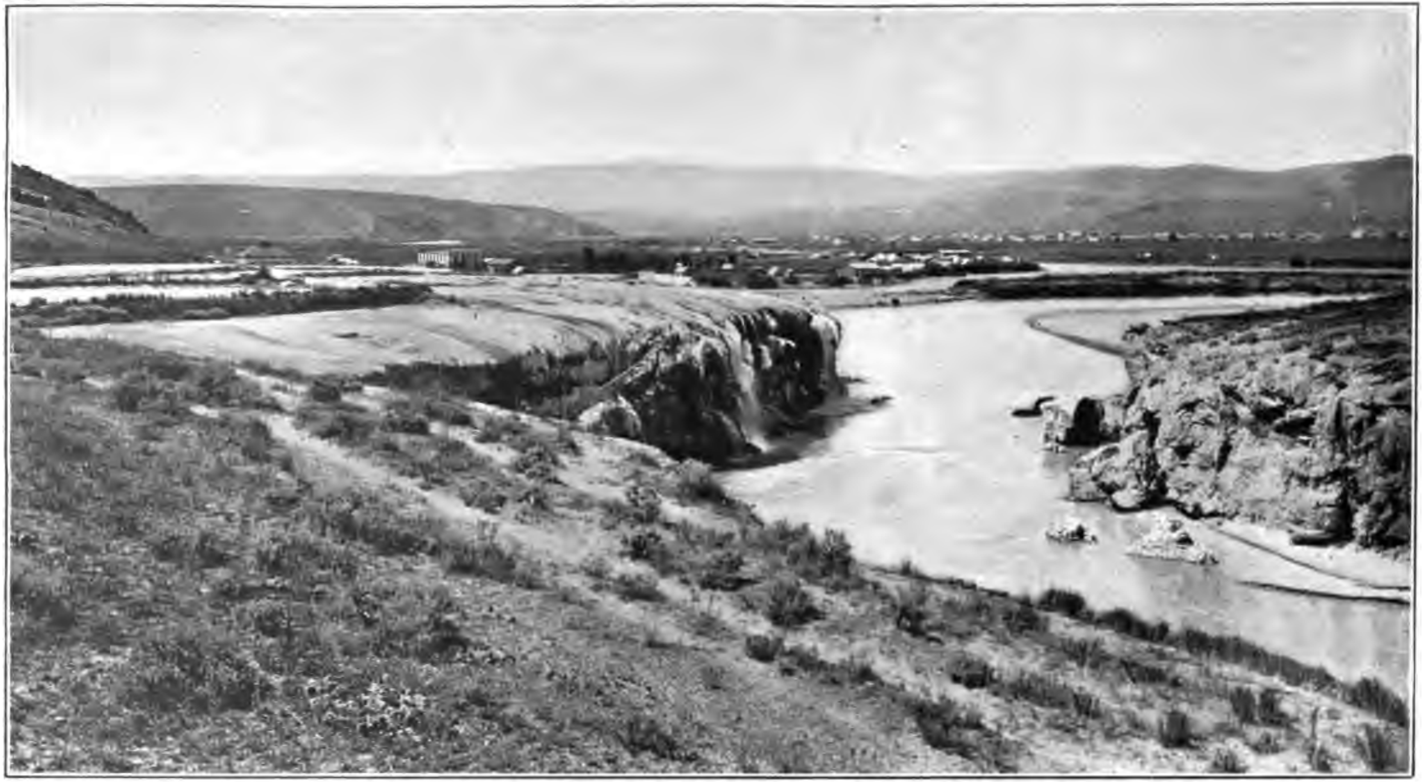
Small amounts of petroleum are occasionally observed in the sandstones and sandy shales in the lower portion of the Colorado formation, as well as in the Cloverly sandstone. At various localities in Wyoming these beds have proved to be a source of supply for petroleum, both from springs of greater or less extent and in wells. While there is no special ground for believing that these formations will yield oil in the Owl Creek region, yet it may be counted among the possibilities. The distribution of the formations is shown on the geologic map (Pl. I) and their underground relations in the cross sections (Pl. XI). There is probably no chance of finding oil in any of the other formations, for they have not yielded oil in adjacent regions.

SURFACE WATERS.

WIND RIVER.

The principal stream in the Shoshone Reservation is Wind River, which flows from northwest to southeast across the southern-central portion of the reservation. It rises near the junction of the Wind River and Shoshone Mountains, but receives by far the largest amount of its water supply from many vigorous creeks which rise on the northeastern slope of the Wind River Range. West Fork and Crow Creek, which rise in the south end of the Shoshone Mountains, are the principal branches on the north side.

The volume of water in Wind River has not been gaged systematically, and only one record has been obtained—6,209 second-feet, July 15, 1894, at Merritts. This was after the floods of early summer had mostly subsided, but probably the amount is much less in late autumn, and undoubtedly it varies considerably from year to year. The volume of the stream is greatly increased in early summer, when the snow on the mountains is melting rapidly with the rising temperature in the month of June. As large snow fields remain throughout the year in the higher portions of the Wind River Range and to a less extent in the Shoshone Mountains, there is an abundant source of supply through the summer, though as above stated, the amount diminishes somewhat as autumn advances. The streams which flow into the river from the north side below Crow Creek are dry most of the time, but sometimes carry a large volume of water from a local rain during the summer or from the melting of snow in spring. A view of this river is shown in Pl. XIX, *A*.



HOT SPRING DEPOSITS ON BIGHORN RIVER NEAR THERMOPOLIS, WYO.

Looking south to Thermopolis in middle-ground and Owl Creek Mountains in distance.

BIGHORN RIVER.

The Bighorn ranks as one of the great rivers of the West, as it carries a large volume of water throughout the year. Wind River is its main source of supply, but it receives many other affluents in its course across northern Wyoming. No records have been obtained of its volume above Thermopolis, but at that place the following gagings have been made:

Gagings of Bighorn River at Thermopolis, Wyo.

[By A. J. Parshall.]

	Second-feet.
1899—July 28	4,867
August 7	4,204
August 16	2,673
September 14	1,162
1900—May 28	8,500
May 29	10,527
May 30	12,187
September 13	945
September 18	674
1902—June 11	9,080
June 14	8,391
June 16	6,334
1903—March 27	621
May 23	1,953
May 25	1,709
June 20	9,280
1903—June 21	8,444
June 22	7,442
July 18	3,882
July 20	4,024
1904—March 25	290
June 19	12,940
June 22	14,240
July 11	7,117
July 12	7,467
July 17	6,130
July 28	5,008
August 8	3,941
August 11	2,878
August 26	2,084
November 24	438

As Bighorn River receives relatively little water between the mouth of Wind River and Thermopolis, probably the gagings above given represent closely the volume that may be expected along the eastern side of the Shoshone Reservation. Views of Bighorn River appear in Pls. III, V, XIV, XV, and XVI.

OWL CREEK.

Owl Creek rises in the south end of the Shoshone Mountains, where a moderately large volume of water is rapidly gathered from springs and melting snow banks. It flows eastward along the northern side of the Owl Creek Mountains, its main or South Fork cutting through a prominent spur of that range 15 miles above Embar. The creek is similar to other streams in the general region in having a considerable increase in its volume in the early summer and a gradual diminution through the late summer and autumn. At intervals below the canyon the water is utilized for irrigation, so that the volume at the mouth of the creek is usually very small. At the head of the canyon the estimated flow is 20 second-feet at the end of summer. North Fork carries considerably less water than the main creek and Middle Fork is but a small rivulet. Several branches rising on the north slope of the Owl Creek Mountains have very small flows, in most cases diminishing to less than 1 second-foot during the latter part of the summer. Mud Creek, the principal branch on this side, has a relatively large watershed as compared with the others and a small flow probably throughout the year.

MUDDY CREEK.

Muddy Creek rises in the western portion of the Owl Creek Range and, after leaving the highlands, flows southeastward across the plains to Bighorn River. In its upper portion there are numerous springs, mostly of good volume, but the branches which they feed dwindle in size in their eastward flow owing to evaporation and absorption by porous strata, so that in the plains area the creek is of small volume.

Sheep Creek, the principal affluent of Muddy Creek, rises on the south slope of the west-central portion of the Owl Creek Range and, though it is fed by numerous vigorous springs, the volume of flow near its mouth in midsummer probably does not average over 2 second-feet.

CROW CREEK.

Crow Creek rises on the southern slopes of the Shoshone Range southwest of the Washakie Needles and flows southward into Wind River. Its volume in August, 1905, was found to be about 15 second-feet, which probably is near the average summer flow. The volume diminishes somewhat toward the mouth of the stream.

DRY CREEK.

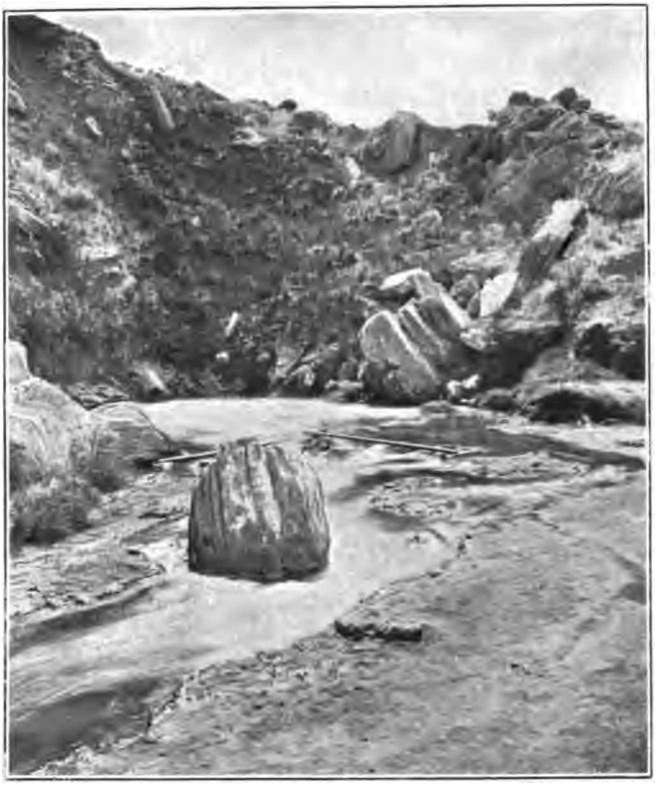
Dry Creek rises in the southern spurs of the Shoshone Mountains and is fed by several running branches (of which Red Creek is one) that have a volume of from 2 to 6 second-feet in midsummer. Below the junction of the various branches the volume of the creek rapidly diminishes and in the lower portion of its course during most years the water sinks or barely flows at the end of summer.

THERMOPOLIS HOT SPRINGS.

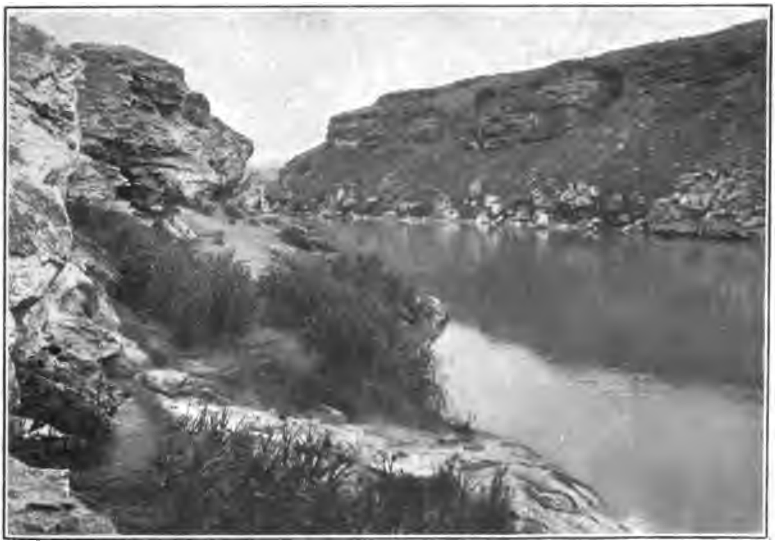
The village of Thermopolis is situated on Bighorn River at the south end of the Bighorn basin. It owes its existence mainly, if not entirely, to a series of thermal springs, one of large volume, flowing out of the "Red Beds" on the bank of the river. The present springs and their predecessors—for the region has been one of thermal activity for a long time—have built up extensive terraces of travertine, or hot-spring deposits, similar to those in the Yellowstone Park. The hot waters have been utilized for many years as a remedy for rheumatism and other ailments, and for this reason the locality has become a widely famed resort for persons desiring hot-water treatment. The spring area has been made a State reservation and bath houses have been erected by the State and by various companies. The waters are employed mainly in two bath houses, a sanitarium, and two swimming pools. An area has been set aside for campers and a large proportion of the visitors go in wagons and camp on the river banks, not only for treatment but for the outing and to see the many novel features which the region exhibits. On a smooth, wide, low terrace on the west side of the river a typical western village of moderate size has grown, with numerous stores, saloons, dwellings, hotels, and other features. An iron bridge affords communication across the river, for the spring resort is mostly on the east side, at a distance of nearly half a mile from the village. Stage lines connect Thermopolis with Casper on the south, Meeteetse and Basin on the north, and Lander on the southwest. Casper was formerly the terminus of a branch of the Chicago and Northwestern Railroad, but this line is now building westward to the eastern margin of the Shoshone Reservation at a point 25 miles south of Thermopolis. From Meeteetsee and Basin there is stage communication to Cody, the termination of a branch of the Chicago, Burlington and Quincy Railway.

STRUCTURE.

The geologic structure at Thermopolis is relatively simple and, owing to the extensive exposures of the formations, is clearly exhibited. (See section 6, Pl. XI.) To the south rises the prominent anticline of the Owl Creek Mountains. Some of the younger formations of these mountains are again uplifted in a sharp local anticline, the axis of which crosses Bighorn River a short distance below Thermopolis. In the central portion of this local uplift a narrow area of the Chugwater red beds is presented, with a succession of Jurassic and Cretaceous strata on either side. Thermopolis is on the eastern limb of the uplift, the village extending across the outcrop zones of the Jurassic and adjacent overlying beds.



A. THE GREAT HOT SPRING NEAR THERMOPOLIS, WYO.



B. THE SULPHUR SPRING ON BANK OF BIGHORN RIVER, 1 MILE BELOW THERMOPOLIS, WYO.

Looking north. Shows high banks at hot spring deposits.

SPRINGS.

The springs rise from the middle strata of the Chugwater red beds, apparently through a number of deep cracks. The largest one emerges from the foot of a high bank of soft red sandstones (see Pl. XV, *A*) and is stated to have a volume of over a thousand gallons a minute. The water is clear and has a temperature reported to be 136°. It flows over a wide terrace built of hot-spring deposits, over the edge of which it falls about 40 feet into the river, as shown in Pl. XIV. A part, however, is diverted into conduits of various kinds, which lead to the bath houses and to reservoirs in which a portion of the water is cooled, so that it may be used for reducing the hot water to the required temperature for bathing. The spring flows with great force and evidently comes from considerable depth under high pressure. Numerous algæ of various colors grow in the hot and cooling water, as in the Yellowstone Park and other places. Besides the main spring there are on the east side of the river a deep, hot pool which does not overflow, and some distance farther north a hot sulphur spring, which gushes out of the travertine bank a few feet above the river, as shown in Pl. XV, *B*. On the west side are several small springs, one of which is utilized for a bath house and swimming pool. An analysis of the water from the great spring, by Prof. E. E. Slosson, is as follows:

Analysis of water of hot spring at Thermopolis, Wyo.

	Grains per gallon.		Grains per gallon.
Silica	4.99	Magnesia sulphate	19.44
Iron and alumina	.23	Lime sulphate	13.15
Potassium chloride	10.25	Lime carbonate	40.45
Sodium sulphate	15.11		
Sodium chloride	26.19		129.81

HOT-SPRING DEPOSITS.

The hot-spring deposits in the vicinity of Thermopolis indicate a long period of accumulation, for they occur on several distinct terraces which date back probably to Tertiary time. The most recent deposits are being laid down on a broad terrace about 40 feet above the river, which is being built up very gradually. No precise estimate has been made of the rate of increase, but objects placed in the water are rapidly coated with the deposit and a thickness of an eighth of an inch is accumulated in a short time. On both sides of the river below the present springs are wide areas of the deposit which were formed at no distant date by springs now extinct, while on the buttes which rise above this terrace level there are caps of hot-spring deposits at various elevations. Some of the relations of these are shown in fig. 1 and Pl. XVI, *A*. The highest deposit caps a prominent butte near the cemetery at an altitude of about 700 feet above the river. A larger terrace remnant remains on a butte which rises immediately west of the river and is about 350 feet above the water. It

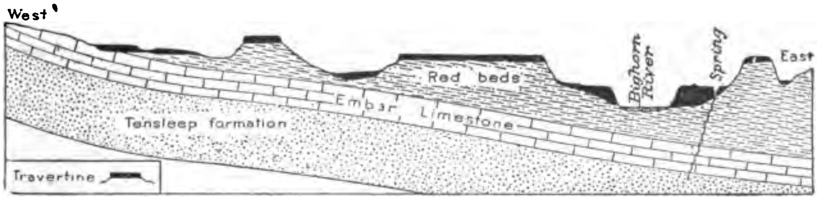


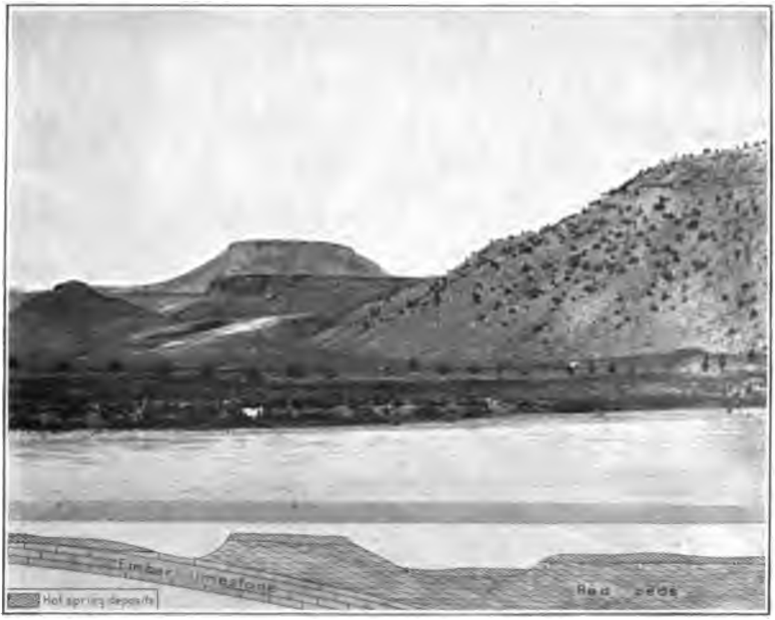
FIG. 1.—Cross section from west to east, showing relations of various terraces of hot-spring deposits north of Thermopolis, Wyo.

is probable that these three principal terrace levels represent three distinct stages of accumulation, and though possibly hot-spring deposition has been continuous since the formation of the first or highest terrace, most of the deposits at intermediate levels have been removed. As hot-spring deposits are often laid on slopes, it is possible that the waters escaping at the level of the higher buttes flowed to somewhat lower levels with a continuous deposit from one to the other. It is evident, however, from the existing relations, that there has been extensive erosion since the earliest period, or the one marked by the highest terraces now remaining, and the high butte near the cemetery is probably the remnant of a much more extended sheet of the deposit which was largely removed before the development of the lower terraces.

The disposition of the material shows that the springs have shifted their position, but in general the principal outflow has been in the immediate vicinity of the crest of the anticline and has traveled from south to north. The hot-spring deposits show remnants of numerous hot-spring craters and cracks, some of the most marked of which are on the terraces near the river. On the west bank, a short distance north of the bath house, there is an empty crater 30 feet in diameter, indicating the former existence of a large hot pool, and another similar crater of still larger size occurs a short distance northeast of the sulphur spring on the east bank. Another of the same character, but much less distinct, is found on the high terrace west of the cemetery, 500 feet above the river. It is probable, from the present appearance of the deposits, that formerly the hot-spring activity was much greater than at present. Whether or not there were geysers is difficult to state, but some of the features of the deposits strongly suggest that if the water was not thrown out by geyser action it at least flowed in large volume.

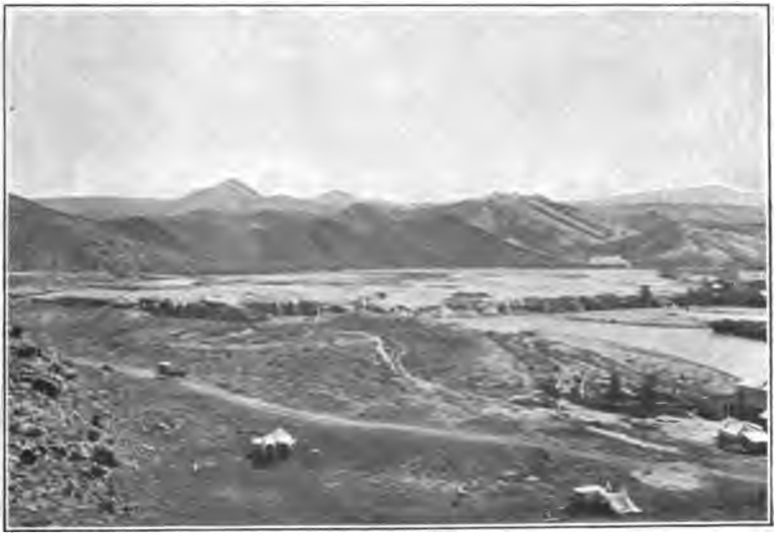
SOURCE OF THE WATER.

The source of the water in the Thermopolis springs is difficult to ascertain. Undoubtedly the flow is not derived from the adjacent red beds nor from the underlying Embar limestone. Probably the strata are somewhat fractured in the crest of the arch of the uplift and permit the escape of the water from a great depth. One of the most likely sources would appear to be the porous Tensleep sandstone, which outcrops high on the mountain slopes to the south and undoubtedly carries a water supply which passes beneath the syncline south of Thermopolis with sufficient head to rise to and above the surface in any vent to the north. If the water is from no greater depth than this horizon, there is difficulty in accounting for the high temperature, for the top of the sandstone does not lie at a greater depth than 500 feet at the spring and 2,000 feet in the bottom of the syncline a short distance south. Assuming that the mean annual temperature at Thermopolis is 50° and that the temperature of water increases one degree for every 50 feet underground below the first 50 feet—in which the mean annual temperature is the underground temperature—a depth of about 4,000 feet would be required under ordinary conditions for the spring water to become as heated as it is. As the granite probably lies only 2,500 feet below the spring, or 4,000 feet below the surface in the syncline to the south, this rate of increase would indicate a source at least as low as the base of the Deadwood formation. If the water is derived from the basal sandstone of that formation, it passes underground in the high mountain slopes to the southeast and receives its heat in the bottom of the syncline a short distance south of Thermopolis. It is possible that the source of the water is much less deep and that the heat is due to deep-seated igneous rocks which have not yet cooled, but there is no evidence of igneous rocks nearer than Shoshone Mountains.



A. OLD HOT SPRING DEPOSITS CAPPING TERRACES AT 4 DIFFERENT LEVELS IN THE WESTERN PORTION OF THERMOPOLIS, WYO.

Looking southward across Bighorn River.



B. THE TERRACES OF HOT SPRING DEPOSIT AT THERMOPOLIS, WYO.

These terraces are covered by the overflowing waters of the great spring, containing varicolored algæ.

UNDERGROUND WATERS.

Among the sedimentary rocks which appear at the surface in the Owl Creek uplift there are several sandstones which undoubtedly contain water in their extension underground. They absorb water in their outcrop areas along the mountain slopes and their dip carries them underneath the adjacent plains, where most of them are covered by shales of an impervious nature. To this extent the conditions for underground water are favorable, but in some portions of the area, owing to steep dips, the water-bearing beds in the older formations pass rapidly to such great depth under the plains that they could not be reached by ordinary well borings. The principal underground conditions are shown in the cross sections of Pl. XI.

In the greater part of the Wind River basin area south of the Owl Creek Range there is a thick covering of the "Bridger" formation, which so masks the underlying rocks that the structural relations can not be ascertained.

CLOVERLY SANDSTONE.

The Cloverly sandstone, which represents the principal water-bearing horizon (Dakota-Lakota) under the central Great Plains, lies at a great depth in the area adjoining Muddy Creek, except in the immediate proximity of the mountain slopes. In portions of the valleys of Pierre and Colorado shales, in the area between Muddy and Red creeks, west of the line of section 4, Pl. XI, and in the vicinity of Owl Creek and Bighorn River, the formation could easily be reached, and on the lower lands probably would yield flowing wells. Along the south side of the western part of the range the top of the Cloverly sandstone lies at a depth of about 1,500 feet at the Pierre-Colorado contact. In Owl Creek Valley the depth is about 1,200 feet at Middleton and for 4 or 5 miles up and down the valley. In range 98 the depth diminishes toward the small anticline 4 miles east of Embar ranch, which brings the formation to the surface. Along the valley west of this anticline the depth to the Cloverly sandstone varies from 600 to 800 feet and then diminishes rapidly as the formation rises to the surface a short distance east of Embar post-office.

In the valley of Mud Creek, southeast of Middleton, the Cloverly sandstone could be reached by wells of very moderate depth—100 to 300 feet—and near the mouth of the creek at 700 feet, and probably would yield flowing wells. The conditions are also favorable in the shale area on either side of Bighorn River a short distance above Thermopolis, where the Cloverly sandstone lies only a short distance below the surface in the syncline. Owing to the outcrops of the sandstone in the Thermopolis anticline, both on Owl Creek and Bighorn River, the water contained in it is free to escape at lower levels than that of the intake zone on the mountain slopes farther south. Because of this condition it is probable that the head of the water will be too low to afford a flow in the immediate vicinity of the Cloverly outcrops on the south slope of the Thermopolis uplift. On the north side of this uplift there are slopes and valleys of Pierre and Colorado shales in which the Cloverly sandstone could be reached at moderate depths, as shown in sections 1 and 2, Pl. XI, and probably flowing wells could be obtained in the lower portions of the area.

South of the Owl Creek Mountains the underground water conditions present much diversity, and as the greater part of the region is covered by Tertiary deposits the relations of the deeper-seated water formations could not be ascertained. East of the syncline southwest of Hollands the Cloverly sandstone dips steeply at the foot of the mountain and rapidly passes to such a depth underground that it could not be reached by ordinary well boring. To the southwest, however, in the shale areas lying south of West Fork of Muddy Creek and along the valley of Dry Creek, this sandstone could be reached at a depth of about 1,500 feet along the line of outcrop at the base of the Pierre shale and at a correspondingly less depth as the Colorado formation is crossed toward the Cloverly outcrop. Probably a flow could be obtained in the lower valleys in this area.

TENSLEEP SANDSTONE.

The Tensleep sandstone is a porous rock which undoubtedly absorbs a large amount of surface water and carries it underground. In most portions of the valley area adjoining the mountains the formation lies at a depth too great to be reached by ordinary well boring. (See sections in Pl. XI.) In some of the valleys in the mountains, however, and along Bighorn River south of Thermopolis, the formation could be reached by wells of moderate depth. It lies about 1,050 feet below the top of the Chugwater red beds and about 250 feet below the base of these beds or the top of the Embar limestone.

As the water enters the formation on the high mountain slopes, it probably has a head so great that it would afford flows in all the valleys and lower slopes, especially in the upper valley of Red Creek southwest of Thermopolis. It is possible that the great spring at Thermopolis draws its water from this source, and probably that the springs about Hollands and at various other points in the red-bed areas along the lower slopes of the mountains are due to seepage from this sandstone.

COLORADO SANDSTONES.

It is probable that the sandstones at the top of the Colorado formation would furnish flows at moderate depths in the shale valleys on the south side of the mountain, in the vicinity of longitude 109°, in the valley of Owl Creek in the vicinity of Middleton, and in Bighorn Valley near the mouth of Kirby Creek. The depths to these sandstones gradually increase from their outcrop to about 1,000 feet along the Pierre-Fox Hills contact north of the Owl Creek Range and to somewhat over 2,500 feet in the Muddy and Dry Creek regions.

FOX HILLS-LARAMIE SANDSTONES.

The sandstones constituting the supposed Fox Hills formation and those occurring at intervals in the overlying Laramie beds apparently contain water which may possibly be of service for wells in portions of Muddy Creek Valley and the adjoining slopes. In the outcrop area of the formation these sandstones are at moderate depths and probably would not yield flows, but to the south, under the mantle of the "Bridger" formation, they may be encountered by borings of various depths and prove to be very important sources of water supply as far south as Wind River.

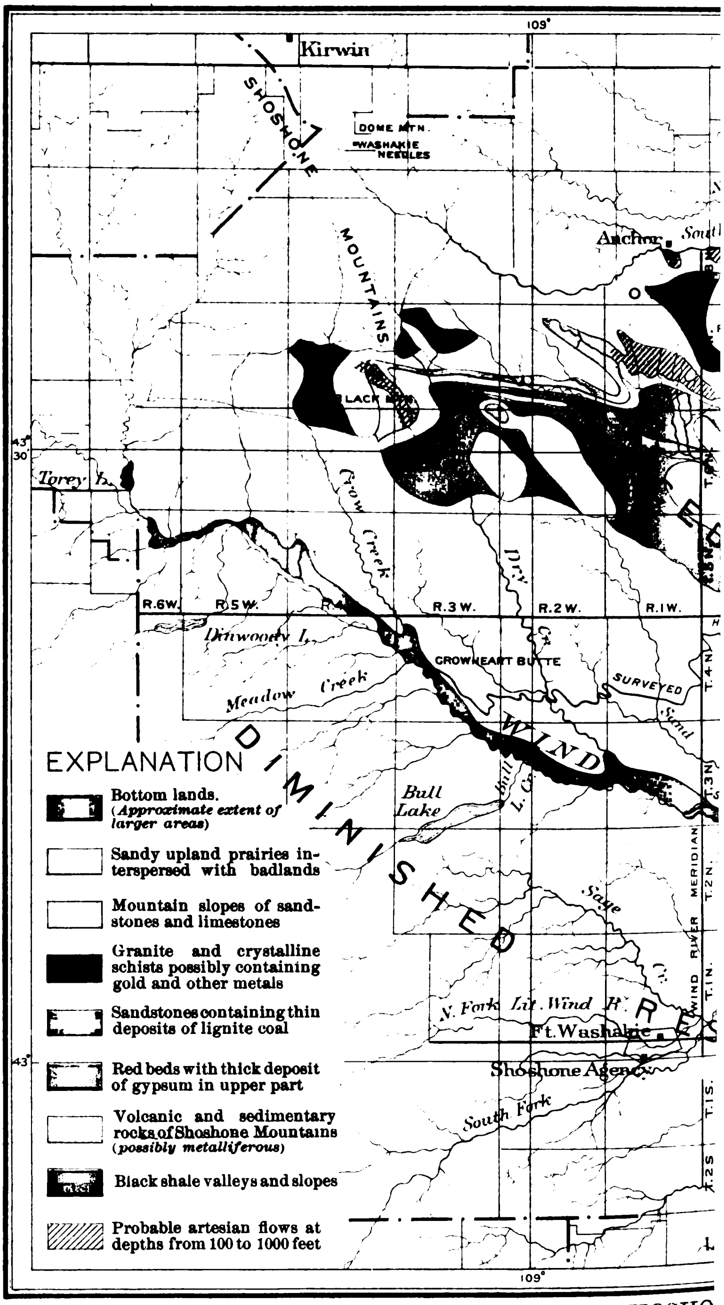
IRRIGATION.

There are several sources of large water supply in the Shoshone Reservation and Owl Creek region, which may be utilized for the irrigation of extensive areas. Wind River and Bighorn River are streams of large volume, and the flow of Owl Creek could be more extensively employed than it is at present. At many localities it would be practicable to store flood waters, and by this means to preserve a supply to be used for irrigation during the growing season. There are wide areas along the valleys and in the low divides between Muddy Creek and Wind River in which the land is favorable for agriculture and to which water could be economically applied.

WIND RIVER BASIN.

GENERAL CONDITIONS.

Preliminary surveys were made in 1904 for a high-line canal to take water from Wind River, a short distance above the mouth of Crow Creek, and carry it across the divides between Muddy Creek and Wind River, and thence, if desirable, down the north side of Muddy Creek Valley. Its course is shown on Pl. XVII. The


109°
Kirwin
SHOSHONE
DOME MTN.
WASHAKIE NEEDLES
MOUNTAINS
Anchor
BLACK MTN.
43° 30'
Torey L.
Crow Creek
Dry Cr.
R.6W.
R.5W.
R.4W.
R.3W.
R.2W.
R.1W.
Dinwoody L.
Meadow Creek
CROWHEART BUTTE
SURVEYED
Sand
WIND
DIMINISHED
Bull Lake
Bull L. Cr.
Sage Cr.
N. Fork Lit. Wind R.
Ft. Washakie
Shoshone Agency
South Fork
43°
T.4N.
T.3N.
T.2N.
T.1N.
T.1S.
T.2S.
WIND RIVER MERIDIAN
EXPLANATION
Bottom lands. (Approximate extent of larger areas)
Sandy upland prairies interspersed with badlands
Mountain slopes of sandstones and limestones
Granite and crystalline schists possibly containing gold and other metals
Sandstones containing thin deposits of lignite coal
Red beds with thick deposit of gypsum in upper part
Volcanic and sedimentary rocks of Shoshone Mountains (possibly metalliferous)
Black shale valleys and slopes
Probable artesian flows at depths from 100 to 1000 feet

ECONOMIC MAP OF THE PORTION OF SHOSHO

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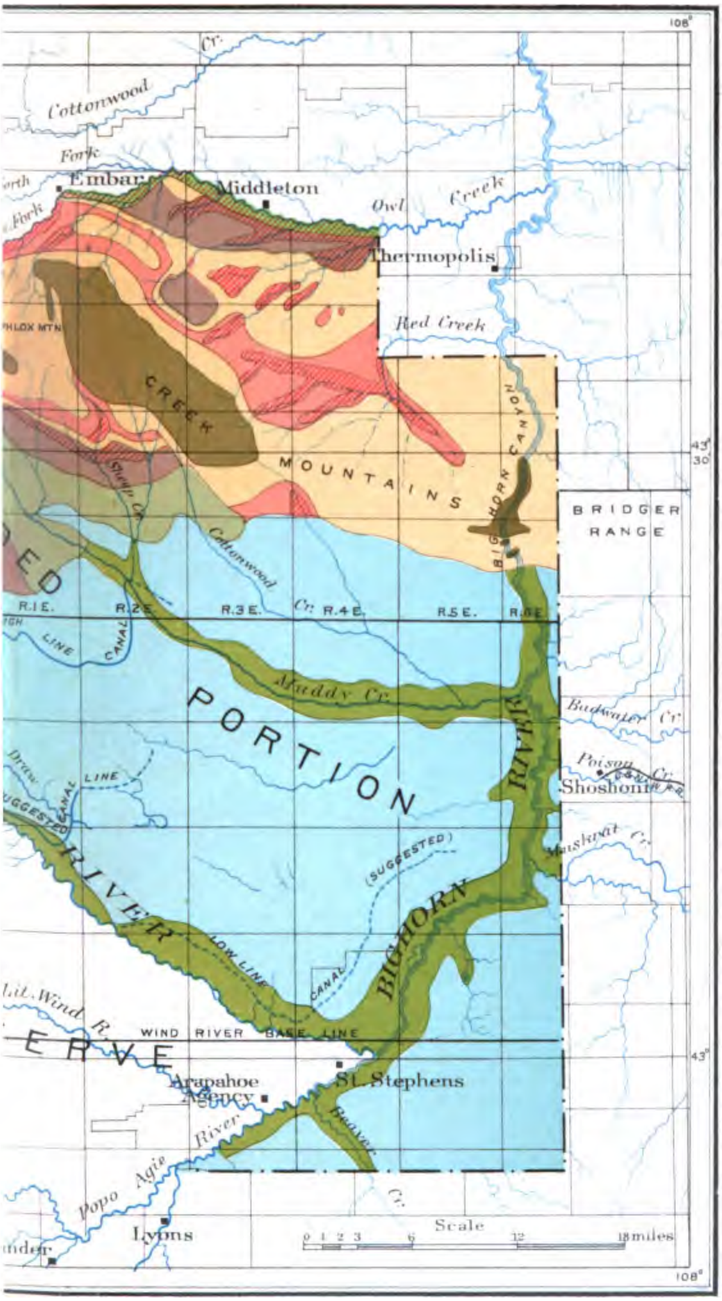
PLATE XVII.



NE INDIAN RESERVATION TO BE OPENED 1906.

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BALTIMORE

point selected was the highest that appeared to be practicable, for the country to the west and northwest is much broken, especially along Crow Creek. It was found that several lower lines would be feasible and two such are shown in the plate above referred to. All of the land below the high-line ditch is rolling and a large proportion is sodded, but there are numerous small, bare areas due mostly to local badland buttes (such as the one shown in Pl. XVIII, *A*, *B*), which range in size from an acre to a quarter section. It has been estimated that over 200,000 acres could be watered. The following statement regarding this project has been prepared by Mr. Goyne Drummond:[a]

"The proposed ceded strip of the Shoshone Indian Reservation comprises an area of approximately 2,283 square miles, extending eastward from North Fork of Wind River on the west to Bighorn River on the east and northward from Big Wind River to Owl Creek. The irrigable area embraced within these borders is approximately 230,000 acres lying east of Crow Creek between Big Wind River and Owl Creek Mountains.

"The greater portion of this land is rolling, but can be easily watered. The soil is a sandy loam, warm and fertile, covered with sagebrush. Wheat, oats, rye, barley, alfalfa, potatoes, and garden vegetables are grown very successfully on portions of this strip, and there is no doubt as to the fertility of the soil when properly irrigated. As the land is rolling and has good drainage very little of it will be injured by seepage water. Within the area are a number of sand-rock buttes, ranging in size from one-half acre to 160 acres and extending over the entire strip between Big Wind River and Muddy Creek. [See Pls. XVIII, *B*, and XIX.] With the exception of that portion lying within the Big Bend of Big Wind River, comprising 20,000 acres, these buttes make it difficult to determine, with any degree of accuracy, the amount of irrigable land, and until a topographical map has been made only an approximation is possible. It is believed that the estimate of 230,000 acres, however, is conservative.

"In the Big Bend of Big Wind River, extending north and west, are about 20,000 acres of fine bottom sagebrush land sloping toward the north and east. North of Muddy Creek, a small stream flowing east through the irrigable land for a distance of 20 miles and then south to Owl Creek Mountains, are 40,000 acres of fine sagebrush land with a slope to the east and south. Between Big Wind River and Muddy Creek is the largest body of land, 190,000 acres.

WATER SUPPLY.

"The source of water supply is Big Wind River and its tributaries, which have an approximate drainage area of 2,000 square miles. A measurement of this stream was made on October 19, 1904, at which time the headwaters had begun to freeze, and its flow was retarded. The discharge was 406.3 second-feet. This measurement was made at a point about 2 miles above the mouth of Bull Lake Creek and about 7 miles below the point of diversion of the proposed canal.

"If the water supply should prove insufficient to irrigate the land without storage reservoirs, there are three reservoir sites above the head of the upper canal with a combined capacity of 121,000 acre-feet. These are in three lakes, viz: Brooks Lake, 25,000 acre-feet; Troy Lake, 26,000 acre-feet, and Dinwoody Lake, 70,000 acre-feet. The last-mentioned lake is in the diminished strip of the Shoshone Indian Reservation, but can not be used for storing water for Indian lands, nor will its use as a reservoir for the proposed ceded strip be of damage in any way to the Indians. If water is stored in it, it will not flood any grazing land, as the surface area will be increased but little. Dinwoody Creek flows from this lake, and measurements taken August 29, 1904, show that it had a discharge of 425.6 second-feet.

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[a] Third Annual Rept. Reclamation Service, 1903–4, pp. 623–624.

"At Bull Lake, which is also on the diminished reserve, a dam 50 feet high could be constructed at little cost which will store 120,000 acre-feet. Bull Lake Creek was measured August 22, 1904, when it had a discharge of 498.9 second-feet. A portion of the water of this reservoir might be used for watering about 20,000 acres of the diminished strip, but as the bluffs along the river are very high and broken the cost would be heavy. This reservoir will not in any way damage the Indian lands should it be necessary to use it for storage purposes.

"The ceded land south and east of Popo Agie River will probably have to be irrigated from stored water, and there are numerous lakes on this stream in the mountains which may be utilized for this purpose. Shoshone Lake, on South Fork of North Fork of Popo Agie River, will have a capacity of 10,000 acre-feet, with a 40-foot dam across its outlet, and the volume of water would be ample to fill it, as the headwaters of this stream are in a region which has heavy snowfall. Big Popo Agie River, below its junction with Little Wind River, August 17, 1904, had a discharge of 592.3 second-feet. North Fork of Popo Agie River August 31, 1904, had a discharge of 118.8 second-feet.

HIGH-LINE CANAL.

"A survey was made during the early part of July, 1904, of a high-line canal. Its head is in the southwest corner of sec. 7, T. 4 N., R. 3 W., at the locality shown in Pl. XIX, *A*. Its source is in Big Wind River, and the waters stored in Brooks, Troy, and Dinwoody lakes can be utilized in this canal if necessary. The course of the canal is eastward, covering the entire strip of irrigable land north of Big Wind River. Its capacity is 1,300 second-feet, its width 50 feet on the bottom, and its slope 1 foot per mile.

"This canal line is located on comparatively level ground and extends about 72 miles to cover 40,000 acres of land north of Muddy Creek. Laterals can be constructed from the canal to cover all the land, but it is believed that other canal lines can be taken out at a less cost than the laterals, and owing to the fact that the fall of the country is too great for the slope of canals, it will be necessary to build a number of drops in them. On the high-line canal are three drops—the first, at a point 36 miles from the head, a drop of 86 feet; the second, at 37 miles, 55 feet; and the third, at 48 miles, 60 feet. These drops are necessary in order to avoid heavy rock side-hill work, such as at the locality shown in Pl. XVIII, *B*, but very little land will be lost by them.

"Another canal line is proposed in order to avoid carrying the water so far in canals. This is taken from Big Wind River, in sec. 36, T. 3 N., R. 1 W., as shown on the maps, and has very little sidehill work. The low line is taken out of Big Wind River, in sec. 32, T. 2 N., R. 2 E. This is also on good ground for construction, with very little sidehill work, and ground of a character to maintain a canal."

BIGHORN RIVER.

Water from Bighorn River could be used extensively for irrigation of the wide bottom lands along that stream, either taken out by ditches or lifted by pumps worked by the power of the stream itself or by other means. No special investigation has been made as to the extent to which irrigation of this sort could be practiced.

OWL CREEK.

The waters of Owl Creek are extensively used for irrigation from the vicinity of Embar eastward and at Anchor post-office. None of the water is utilized on the south side of the stream within the Indian reservation. It is claimed that the present water rights provide for the use of all of the flow of the stream, but if the supply could be increased the wide flats along the south side of the valley in the Indian

A. CROWHEART BUTTE, WIND RIVER VALLEY, WYOMING.

B. SLOPE OF SAND ROCK ON SURVEYED DITCH LINE WHICH WOULD NECESSITATE A DROP IN THE CANAL.

reservation could be irrigated to great advantage. There is a reservoir site at Anchor in which a moderate amount of water could be held by the construction of a dam in the narrow gorge through which the stream passes, a short distance below the post-office, but it would flood the Blonde ranch. Water could also be held by a dam at the head of the deep, narrow canyon of South Fork of Owl Creek, in range 102. As there is much more water in the upper course of the stream than is found farther down, doubtless a large supply could be obtained in a reservoir at this place and held until needed to increase the flow, so as to provide for the filling of ditches on the south side of the valley below Embar.

MUD, MUDDY, AND CROW CREEKS.

Both Mud and Muddy creeks and their branches have numerous reservoir sites in which, by the construction of dams of moderate height, a large volume of water could be held for the supply of local ditches, and along Muddy Creek a large acreage of the gentle valley slopes could be irrigated by this means. The valley of Crow Creek is mostly narrow, but there are many small tracts of open bottom land which could be irrigated, and probably the water supply in the stream is ample for this purpose without holding it in reservoirs. If necessary, it would be practicable to make a reservoir of considerable size on this creek, northwest of Black Mountain, in which a moderate volume of water could be held.

CLIMATE.

The principal meteorological data for the region to which this report relates are the records of the weather observations at Fort Washakie. These have been in progress for many years and illustrate the climatic conditions of at least a portion of the Wind River basin. The records of temperatures and precipitation, from 1891 to 1903, are given in the following tables:

Monthly and annual precipitation at Fort Washakie, Wyo.

[In inches.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1891	1.91	0.18	3.58	2.23	4.58	1.30	0.63	0.31	0.92	3.50	0.46	0.28	19.88
1892	.75	.30	1.37	2.33	3.51	.71	.62	.32	.00	.45	9.83	1.04	21.23
1893	.50	.54	.20	2.00	1.89	.62	.07	1.05	.12	.18	1.40	.37	8.94
1894	.09	.45	2.67	.92	1.08	.41	.38	.09	2.22	.00	.22	.00	8.53
1895	.18	.76	7.90	7.25	.55	1.91	.64	1.10	2.17	.85	1.93	.00	25.24
1896	.25	.20	1.62	1.60	2.13	.60	1.67	1.19	.93	.46	.42	.00	11.07
1897	.12	.67	.77	1.00	1.75	1.13	.98	.30	.11	1.00	.42	2.14	10.39
1898	.23	.00	1.42	.87	5.77	2.87	.35	.46	.30	1.75	.03	.29	14.34
1899	.51	.35	.83	.45	2.01	.81	.75	1.75	.59	1.39	.00	.29	9.73
1900	.01	1.00	.56	6.81	.42	1.00	1.80	.70	1.65	.55	.02	1.10	15.62
1901	.20	.04	.03	3.10	2.90	1.70	Tr.	.59	.24	.19	.21	1.26	10.46
1902	.26	.16	1.15	1.74	.61	.54	.40	.01	.56	.90	.05	.05	6.48
1903	.20	.13	1.80	1.90	1.25	2.00	.80	.44	2.11	1.87	.00	.50	13.00
Average	.40	.36	1.84	2.47	2.19	1.20	.70	.63	.92	1.01	1.15	.56	13.45

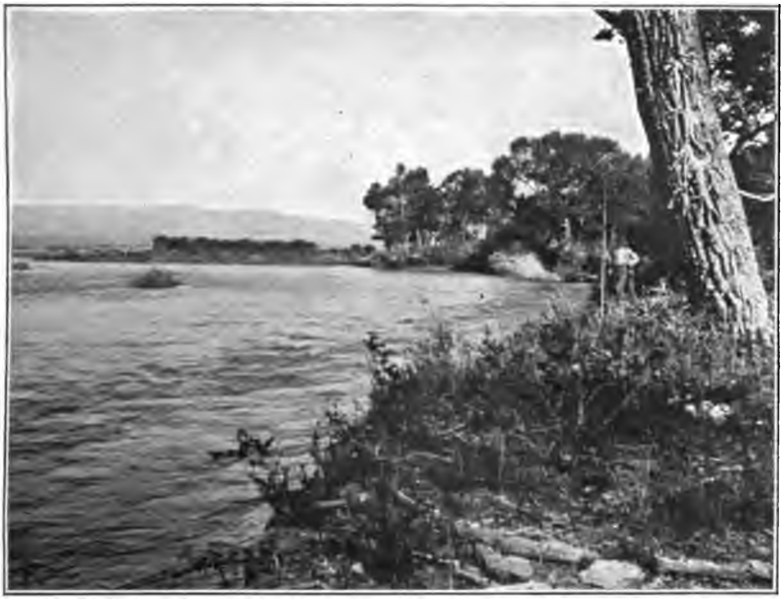
Mean monthly temperature, etc., at Fort Washakie, Wyo.

[Temperatures (° F. In round numbers).]

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.			Killing frost.	
													Mean.	Maximum.	Minimum.	Last in spring.	First in autumn.
1891........	20	17	24	42	51	56	65	71	57	45	32	23	42½	90	−29	May 23	....
1892........	19	27	36	39	48	59	68	65	59	46	34	16	43	94	−30	June 4	Oct. 11
1893........	30	21	30	37	49	61	68	65	56	44	27	28	43	97	−11	May 31	Sept. 14
1894........	21	15	32	43	59	60	67	68	53	46	37	20	43	93	−26	....	....
1895........	19	20	30	46	50	56	64	65	55	42	28	20	41	92	−26	June 18	Sept. 7
1896........	26	29	29	39	48	62	67	65	54	44	25	28	43	96	−30	....	Sept. 27
1897........	16	23	27	42	57	59	65	65	59	44	34	18	42½	92	−30	June 17	Sept. 18
1898........	14	30	27	45	48	59	66	66	55	40	29	18	41½	91	−23	May 21	Sept. 7
1899........	21	10	28	43	48	57	66	64	59	43	38	23	41½	93	−35	June 9	Sept. 28
1900........	29	19	38	44	55	66	65	65	54	46	35	28	45	95	−34	May 1	Sept. 25
1901........	23	17	32	41	57	59	71	67	53	47	35	23	44	99	−28	June 5	Sept. 16
1902........	21	31	32	43	55	63	66	67	56	48	34	23	45	99	−33	May 22	Sept. 12
1903........	25	19	31	42	50	62	67	67	53	48	35	25	43½	92	−28	May 23	Sept. 8
Average...	22	20	30	42	52	60	67	66	55	45	33	22	42	....	....	....	....

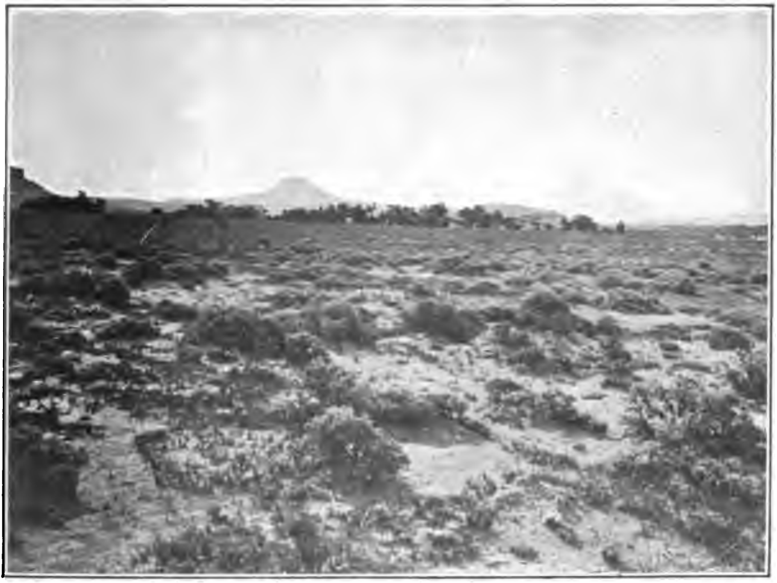
It will be seen from these tables that the precipitation is variable and ordinarily ranges from about 9 to 15 inches, with occasional local increases of considerable amount. Ordinarily April is the most rainy month, but in some years there is greater precipitation in either March or May, and even in both of these months than in April. In midwinter and midsummer there is a general great diminution in precipitation, with a moderate increase to an average of an inch or more in the late autumn. To judge from the vegetation in the plains north of Wind River, probably the precipitation in that area is materially less than at Fort Washakie, which is at the foot of the slope of the Wind River Range. In the Owl Creek Mountains and at the south end of the Shoshones undoubtedly the amount of precipitation is much greater, especially in late autumn and at intervals during the winter when the snowfall is moderately heavy. In the Wind River basin the snowfall is reported to be light and the snow does not remain long on the ground.

The temperatures at Fort Washakie show considerable variation from year to year, especially when the mean monthly temperatures are compared. In midwinter there is a small proportion of intensely cold weather, with temperatures as low as −35° in some years, but the mean winter temperature is in the neighborhood of 25° above zero. At Fort Washakie there is considerable protection from the cold westerly winds, and doubtless farther north, in the plains north of Wind River, the extremes of temperature are greater. In the Owl Creek Mountains the winter temperatures probably are lower, while in midsummer the heat is more moderate than in the lower lands. Owing to the low humidity there is much heat from the direct rays of the sun, especially in summer. During the hot weather the shade is relatively cool and usually the nights are chilly, especially on the higher lands to the north and west.



A. VIEW UP WIND RIVER AT SITE OF INTAKE FOR SURVEYED DITCH LINE.

Wind River Mountains in distance.



B. BOTTOM LANDS NEAR WIND RIVER ON FIRST MILE OF SURVEYED CANAL LINE.

Crow Creek in middle-ground and Crowheart Butte in distance.

TIMBER.

There is a small amount of pine forest at the south end of the Shoshone Mountains and scattered trees on the higher portions of the Owl Creek Mountains. The principal pine is of one species, *Pinus murrayana*, which is called "white pine," "yellow pine," "jack pine," and "lodgepole pine," the different names being applied in part on account of differences in development. The wood is coarse-grained and knotty, few of the trees yield large logs, and, as the lumber warps and cracks considerably, it is not regarded as valuable. The species *Pinus flexilis* occurs scattered among the others. The Engelmann spruce occurs in some moist areas along the mountain slopes of the Shoshones. The pine occurs at altitudes ranging from 6,000 to 10,000 feet. Numerous large cottonwood trees grow on the banks of Wind and Bighorn rivers, and in the valleys of Crow, Owl, and some of the other creeks.

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